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W. F. KING, LATE CHIEF ASTRONOMER FOR CANADA.

C. A. CHANT.

The death of Dr. W. F. King, Canadian Chief Astronomer and Director of the Dominion Astronomical Observatory, Ottawa, causes a decided vacancy in the scientific world of Canada. He was of a very quiet and retiring nature and any recognition which he received was purely through merit. A brief consideration of the many appointments he held will show that his life was a very active and useful one.

William Frederick King was born at Stowmarket, Suffolk, England, on February 19, 1854, and came to Canada with his parents in September, 1862. He received his preliminary education at the public and high schools of Port Hope, Ontario, and in September, 1869, matriculated into the University of Toronto; but before he received the B. A. degree he began his astronomical work. From September 1872 to December 1874 he acted as sub-assistant astronomer on Her Britannic Majesty's North American Boundary Commission, delimiting the boundary between the United States and Canada from the Lake of the Woods to the Rocky Mountains. In June 1875 he graduated from the University, winning the gold medal in mathematics.

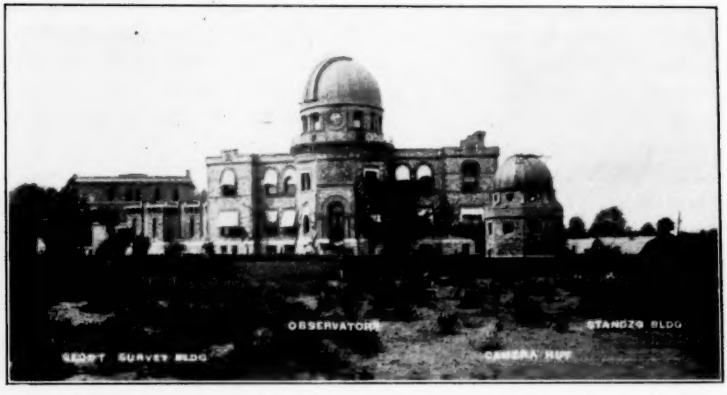
In 1875-76 he was astronomical assistant on special surveys in the North West Territories, and on November 21, 1876, he was admitted a Dominion Land Surveyor and a Dominion Topographical Surveyor. The qualifications for the latter are very technical and difficult and he was the first one to receive the commission. From 1877 to 1881 he was in charge of the astronomical section of the special survey, and on June 13 of the latter year he was made Inspector of Surveys, which was his first permanent appointment in the Department of the Interior.

After this came numerous commissions. From 1885 to 1899 Dr. King was a member of the Board of Examiners for Dominion Land Surveyors. On July 1, 1886, he was appointed Chief Inspector of Surveys, and four years later, in 1890, was made Chief Astronomer of the Department of the Interior. On September 12, 1892, he was

appointed H. M. Commissioner under the convention of July 22, 1892, for the survey of the Alaska boundary and of the water boundary in Passamaquoddy Bay, between Maine and New Brunswick. During 1898 and 1899 he was attached to the Joint High Commission at Quebec and Washington as expert on boundary matters. On September 30, 1899, he was reappointed on the reorganized Board of Examiners for Dominion Land Surveyors, and on November 29 of the same year he became Commissioner for demarcation of the provisional Alaska boundary under the Modus Vivendi of October 29, 1899.

On September 28, 1901, he was appointed Commissioner to coöperate with the state of New York in the renewal of the boundary line from the Richelieu to the St. Lawrence, and on July 10 of the following year was appointed H. M. Commissioner under agreement for re-survey and renewing of monuments from Lake Superior to the Pacific Ocean. On November 11, 1902, he was appointed Canadian Commissioner for re-survey of the Quebec-New York boundary. In April 1903 he was attached to the staff of the British Agent, assisting in the preparation of the case for the Alaska Boundary Tribunal. In December 1903 he was made a member of the International Waterways Commission, which appointment he held until February 1907.

On January 29, 1904, Dr. King was appointed H. M. Commisioner for survey and delimitation of the Alaska boundary under award of the Tribunal made on October 20, 1903; and in April of the same year he negotiated with the United States Commissioner the definition of



THE DOMINION OBSERVATORY, OTTAWA, CANADA.

that portion of the boundary which was left undetermined by the Tribunal which met in London. On April 15, 1905, he became Director of the newly-established Dominion Astronomical Observatory. On

July 7, 1906, he was appointed H. M. Commissioner for surveying the boundary from the Richelieu to the St. Croix river, and on July 23 of the same year he received the appointment of H. M. Commissioner for survey of the 141st meridian under the convention of April 21, 1906.

On April 6, 1908, he was appointed representative of the Canadian Government in negotiations relative to the uses of international waters for the purposes of irrigation. In June 1908 he was named H. M. Commissioner under the Boundaries Delimitation treaty of April 11, 1908. During 1909 he was representative of the Canadian Government in the Passamaquoddy Bay negotiations which resulted in the treaty of May 21, 1910. On April 20, 1909, he was made Superintendent of the Geodetic Survey of Canada, then just initiated. His commission as H. M. Boundary Commissioner under the treaty of April 11, 1908, is dated October 6, 1915, and is under the Royal Sign Manual.

One cannot read the above list of appointments without recognizing the extreme value of Dr. King as a public servant, and we are not surprised that various honors were bestowed upon him.

On June 11, 1904, the University of Toronto conferred on him the degree of LL. D. (Honoris Causa). In the work of the Royal Astronomical Society of Canada Dr. King took great interest, and was active in the formation of the Center at Ottawa. He became its first president, and, besides, he was Honorary President of the whole Society from 1906 until his death. He was made a Fellow in 1909.

In March 1907 he was elected Honorary President of the Association of Dominion Land Surveyors. In 1908 he became Fellow of the Royal Society of Canada; in 1910 and 1911 he was vice-president, and in May 1911 was elected president.

In June 1908 he was created C. M. G., that is, Companion of the Order of St. Michael and St. George. This honor is conferred by the British sovereign. Since 1908 he was a member of the society now known as the American Astronomical Society, and in December of the year just named he was made Honorary member of the Mexican Astronomical Society.

For the marked activity in astronomical matters in Canada during recent years Dr. King should receive much credit. After many years of effort the beautiful brown stone building of the Dominion Observatory was erected, and around it have been grouped various buildings for the Geodetic Survey and other branches of the service. It is to be regretted that he did not live to see the completion of the great 72-inch reflecting telescope and the buildings to be attached to it at the Victoria station of the Observatory. It is expected that the instrument will be in operation in the autumn and that a regular program of work will be entered upon next spring.

With so many administration duties to perform Dr. King had little leisure for original scientific contributions. I might mention, however, a valuable paper on "Least Squares", printed in the Journal of the Royal Astronomical Society of Canada, and one on "The Geometry of Orbits", which appeared in the Astrophysical Journal. In the latter is presented an entirely original and ingenious method for rapidly obtaining, by graphical means, the elements of the orbit of a spectroscopic binary. This method has been found very useful at the Dominion Observatory and elsewhere.

It has been said that there is no better way to know a man than to camp with him for two or three weeks. The present writer was acquainted with Dr. King for a considerable number of years, but in 1905 he had the privilege of closely associating with him in the camp at North West River, Labrador, whither we had gone to observe the total eclipse of the sun. On cold evenings as we gathered about the campfire and joined in the general entertainment with song or joke, Dr. King threw aside somewhat the cloak of reticence in which he was usually wrapped and gave us some of Bret Harte's poems. He stood the camping test; the nearer we came to him, the more did his sterling character show itself.

In church work Dr. King was identified with almost every department of Christian activity. At the time of his death he was representative to the provincial and general synods of the Anglican Church.

On the 13th of June 1911, to commemorate the thirtieth anniversary of the director's first appointment in the Department of the Interior, his united staffs presented him with a magnificent loving-cup, upon which is engraved the record of his achievements, appointments and academic distinctions.

Dr. King's health had not been very good for some time but he was able to continue his work. However, early in the year he was advised to take a rest at a health resort; he did so, but there was no improvement, and he returned to his residence near the Observatory, where he passed away on Easter Sunday, April 23.

To mourn his loss he left his widow, Augusta Florence Snow, daughter of John A. Snow, D.L.S., whom he married in 1881; two sons, Frederick W. and Edward A., at home; a daughter, the wife of Mr. R. M. Motherwell, astronomer at the Observatory; and a sister, Mrs. James Reid, of Port Hope, who was with him during his illness.

Toronto, Ont.

THE HISTORY OF THE DISCOVERY OF THE SOLAR SPOTS.

WALTER M. MITCHELL.

[*Continued from page 303.*]

The Rosa Ursina.*

Frequent mention has been made of the *Rosa Ursina*. This was Scheiner's great book on the solar spots. A ponderous quarto of nearly eight hundred pages, of which Delambre very unjustly remarks, "There are few books so diffuse and so void of facts. It contains 780 pages, but there is not material in it for 50." It was devoted exclusively to the subject of the sun and its spots, and contained observations extending over a period of more than sixteen years. The title, eminently suitable for a work of such magnitude was, *ROSA VRSINA, SIVE SOL, EX ADMIRANDO FACVLARVM & Macularum suarum Phoenomeno VARIVS, NECNON Circa centrum suum & axem fixum ab occasu in ortum annua, circaq. alium axem mobilem ab ortu in occasum conuersione quasi menstrua, super polos proprios, Libris quatuor MOBILIS ostensus,* a CHRISTOFORO SCHEINER GERMANO SVEVO, E SOCIETATE IESV. AD PAVLVM IORDANVM II. VRSINVM BRACCIANI DVCEM. BRACCIANI, Apud Andream Phaeum Typographum Ducalem. Impressio coepta Anno 1626, finita vero 1630. Id Iunij.

For an explanation of this extraordinary title, we quote Kästner, who remarks in his *Geschichte der Mathematik*:†

> Weil der damalige Herzog von Bracciano aus die Familie Ursi [Orsini] war, und weil die liebe Sonne nichts dagegen sagt, wenn man sie mit einer Rose vergleicht, so heisst das Buch von der Sonne, dem Herzog dedicirt, Rosa Ursina.

The book was dedicated to Paulus Jordanus II, Duke of Bracciano, a member of the house of Orsini. The rose was the emblem of the Orsini family, and as a delicate compliment to his patron, Scheiner proclaims the sun, "The Rose of the Orsini"! The dedication is well enough, for doubtless somebody had to pay for the publication, but that the mighty orb of day should be presented to the Duke as a bouquet, seems to be

* I take pleasure in acknowledging my indebtedness to Professor E. B. Frost of the Yerkes Observatory for the loan of the copy of the Rosa Ursina from which the accompanying illustrations were made.

† Band 4. p. 149.

carrying the compliment a little too far. This motif—"The Sun, the Rose of the Orsini"—is carried out through all the book. On the reverse of one of the title pages (Plate XVIII) is a portrait of the Duke, Paulus Jordanus, himself, surrounded by a wreath made up of alternate roses and suns well supplied with spots.

A picture on the main title page (reproduced in Plate XIX) shows a sort of mountain surmounted by two rose-bushes; three bears in as many caves, the entrances of which are gracefully draped with entwined roses, are performing various duties. Above and below are the mottoes, "Rosa Ursina", "Ursa Rosina". These "rosy bears" naturally furnished Scheiner's enemies with a target for their jokes. Galileo writes to his friend Fulgenzio Micanzio, 9th of February 1636: *

> I admire your persistence in reading the Rosa, in which there is so much pompous childishness. But you will tell me that the very fact that it contains such an excessive amount of this causes no small joy. And who will not pause in considering the cleverness in printing the three she-bears in the three caves, one of which perceives the spots on the sun, the other licks her cubs, and the third sucking her paws? With two such appropriate mottoes (Constans industria format; Ipse alimenta mihi), and the clever transposition $\begin{matrix}\text{Rosa Ursina}\\ \text{Ursa Rosina}\end{matrix}$. But why should I relate the playful pranks of these little animals for they are innumerable.

It is somewhat difficult to get at the subject matter in this book, which is an interminable labyrinth of words. Page after page, with great double columns, filled with arguments, corollaries, lemmas, queries and answers, without number or end. Even the smallest details are discussed forward and backward, through secondly and thirdly, occasionally up to thirty secondly and even fortiethly, in the most elaborately prosy and prolix fashion, and one can only wonder that four and not forty years were required to finish this enormous work. Nevertheless the book itself is a splendid example of the printer's art of that day, and when one recalls that printing was scarcely two hundred years old, one can but admire the clear and legible typography and the fine and beautifully made engravings.

Obviously it will be impossible to condense all the material of value in the *Rosa* (and there is more of it than Delambre would have us believe) into the limited space of this paper. But there is such a wealth of information concerning the phenomena of the sun's surface, obtained through the unusual skill and perseverance of Scheiner as an observer, that in justice alone the more prominent facts must be mentioned.

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* *Gal. Op.* **16**, 391.

In the preface, "Ad Lectorem" Scheiner relates the history of his discovery of the solar spots, as follows:*

Therefore in 1611 at the University of Ingolstadt, I, Professor of Science, in the month of March, having climbed to the tower of the Temple and directed the telescope at the sun, weakened proportionately by a moderate cloud; not as a result of any previous report, but spontaneously, led by my desire of examining the sun, I first found solar spots. My companion was J. B. Cysat, a student of theology, who at that time strongly urged me to prepare colored glasses, and while I was doing this, in the month of October of the same year there came again as there will, some days overcast with light clouds inviting observations of the sun, so that I directed my telescope from my bed-chamber.....that is, on the 21st day, German Astronomical Time 21 hours; at 9 in the morning, and I saw spots for the second time. And I showed them to many other Fathers and students, until 10 o'clock, at which time Father Adam Tanner perceived the same spots from his bed-chamber.....on account of some previous rumors, as he says, of which, however, not the faintest whispers had reached my ears before the spots were first seen by me. For the March observations of these, which were the first, I had not divulged up to that time.

The body of the work is divided into four books. The first of these is largely a denunciation of Galileo, with an attempt by the author to defend himself against the accusations made in the *Saggiatore*. It contains an account of the author's claims for priority of discovery, and a criticism of Galileo's observations and theory of the spots, as contained in the *Istoria*, all of which are related with wearisome longwindedness in some sixty odd pages. In this first book Scheiner gives† a catalogue of the errors into which Galileo had fallen in his reasonings concerning the spots. These errors, which are divided into 24 heads, and were exploited with evident glee by Scheiner were very obvious and were subsequently corrected by Galileo in the *Dialogues on the Two Chief Systems of the World*. This catalogue of errors put Galileo into a rage, as we learn from the letter to Micanzio, in which the "rosy bears" are ridiculed. Galileo continues:‡

This pig, this great malignant ass [that is to say, Scheiner] makes a catalogue of my errors, which result from one only, which was at first unknown to him as it was to me, namely, the very small inclination of the sun's axis to the ecliptic. I am sure that I discovered it before he did, but had no occasion to mention it except in the *Dialogues*. But let the fellow see his bad fortune, for he was unable to deduce anything remarkable from this observation, while I discovered through it the greatest secret that there is in nature [meaning the revolution of the earth about the sun], and this discovered by me, and comprehended by him after my announcement, to his extreme wonder, is what has most mortally transfixed him, and aroused him to canine rage against me; since it has been my good fortune alone to observe so many and such great novelties in the heavens, and from them to deduce such great consequences in nature; of which this is, one might say, the greatest. And the unfortunate man who so long held in his hand such a precious jewel did not know how to recognize it.

* *Rosa Ursina*, leaf 14.
† *Ibid.* 45.
‡ *Gal. Op.* **16**, 391.

This "error" that Galileo refers to,—the slight inclination of the sun's axis to the ecliptic, may have been observed by Scheiner before Galileo, as Scheiner was a careful and painstaking observer. At all events Scheiner is the first to mention it. The inclination of the sun's axis to the ecliptic determines the positions and the aspects of the paths of the spots as they cross the disk, with the changes in the curvature and direction of these paths at different times of the year, and is of consequent importance. The fact that Scheiner was unable to deduce from these changes that which Galileo recognized to be their true cause, namely, the different positions of the earth in its orbit around the sun, was undoubtedly due to his deeply rooted conservatism and adherence to the older ideas. But the changes in the paths of the spots could equally well have been explained by the theories of the Peripatetics, although Scheiner did not recognize this, and consequently this did not hold as an uncontrovertable proof of the correctness of the Copernican theory. Nevertheless it cannot be denied that this argument served to weaken the opponents of Copernicus fully as much as many of the other arguments which had been advanced by Galileo.

The second book of the *Rosa Ursina* is devoted to a description of the methods of observation and the instruments that were used by Scheiner. We are told that the period of observation extended over 16 years, and that observations were not only made daily, but that Scheiner was accustomed to observe frequently as many as 10, 20 or more times in one day in order to make a comparison with previous observations or to correct possible errors. It was this painstaking method that, as we shall see, acquainted Scheiner with the manifold changes and transformations which normally take place during the development of the sun-spots and faculae, which he describes in such detail. Evidently by the time that the *Rosa Ursina* was ready for publication, Scheiner had learned that for him at any rate, intuitive reasoning was not safe, for he tells us many times during the course of the book that he does not wish to make a definite statement on this or that point, as there is not sufficient observational data available. This conservatism fortunately not only necessitated his making as many observations as possible, but also showed him the advantage to be gained by varying the methods of observation, in order better to determine the reality of that which he wished to establish.

As we have seen, Scheiner's first observations were made when the sun was near the horizon or was partially obscured by clouds. At the suggestion of Cysat he constructed a telescope in which the lenses were ground from colored glass, with this the sun could be observed at any altitude. This instrument he called "Helioscope," and owing to its

SOL TIBI SIGNA
DABIT.
Virg. 1. Georg.
BRACCIANI DVX ✱ PAVLVS IORDANVS II VRSINVS
VRSINAE Dux Gentis Aue; Tibi plaudit Olympus;
Currit in obſequium Phœbus & Vrſa tuum.
Signa genusq. ſuum mutis incidere faxis
Si potuere alij, Fors ea magna fuit.
SIGNA Genusq. tuum Cæleſtibus indita fulgent
Orbibus; VRSINOS fixit in axe Deus.
Macte animi virtute Heros, genus Alte. Trophæis
Quod nimis arcta tuis eſt humus aſtra petis.
MOECENATI Auctor.
Sol quoque & exoriens & cum ſe condet in undas
SIGNA dabit. Solem certiſſima SIGNA ſequuntur,
Et qua mane refert, & qua ſurgentibus aſtris;
(Quando) naſcentem MACVLIS variauerit ortum.
Virgilius 1. Georg.

Rosa Ursina, DEDICATION TO PAULUS JORDANUS II.

ROSA VRSINA

SIVE

SOL

EX ADMIRANDO FACVLARVM
& Macularum ſuarum Phœnomeno VARIVS,

NECNON

Circa centrum ſuum & axem fixum ab occaſu in ortum annua,
circaq. alium axem mobilem ab ortu in occaſum conuerſione
quaſi menſtrua, ſuper polos proprios, Libris quatuor
MOBILIS oſtenſus,

A

CHRISTOPHORO SCHEINER
GERMANO SVEVO, E SOCIETATE IESV.

AD PAVLVM IORDANVM II.
VRSINVM BRACCIANI DVCEM.

BRACCIANI,
Apud Andream Phæum Typographum Ducalem.

Impreſsio cœpta Anno 1626. finita vero 1630. Id. Iunij. *Cum licentia Superiorum.*

REDUCED FAC-SIMILE, TITLE PAGE OF *Rosa Ursina.*

superiority, smaller details of spot structure and faculae could be seen. Scheiner describes the helioscope as follows:*

> The helioscope consists of at least two colored glasses, convex and concave, of good clear material, with sufficient color, containing neither bubbles nor sand particles, in particular free from veins, streaks, or waves. If, however, the two lenses are not sufficient to diminish the sun's light, one must add one or more pieces of colored glass, plane parallel, well ground and polished.....all these glasses must be placed perpendicular to the axis of the telescope.

That Scheiner had many sad experiences with the opticians of the day, and that any slight advantage which a piece of apparatus might possess became an excuse for raising the price,—a "hold-up" method, which it seems was well known even in that day, is learned from his remarks. Although the construction of lenses from colored glass required no more skill than did the construction from white glass, one finds:†

> That the workmen immediately wished to profit through the desires of the purchaser, and raised the price unbelievably, on account of the advantage of the device, which the purchaser had discovered by himself and through his own industry.

In his earlier observations Scheiner employed the Galilean form of telescope with concave eye lens. Some years previously Kepler had advocated the use of a telescope with convex eye lens as possessing special advantages, particularly in increasing the available field of view. Kepler, it appears never made any practical use of this arrangement, but Scheiner perceived its advantages and at an early date (about 1613) constructed the first telescope of this pattern.

Scheiner mentions in many places in his book the confidence that he has in his telescopes. He describes in great detail the various kinds of lenses, with their combinations, and the advantages possessed by each when employed for solar observations. A clear homogeneous lens is to be treasured like a diamond. The performance of a telescope was judged:‡

> From the size and definition of the image; under otherwise similar conditions the longer telescopes are better.....It is to be noted, however, that the size of the field is in the inverse ratio to the magnification and the definition, so that with this arrangement the sun can only be observed gradually, a little at a time, which is no small advantage.

During his earlier observations Scheiner had perceived that when using the telescope in the ordinary manner, no really valuable results could be obtained, because with this method it was impracticable to

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* *Rosa Ursina*, p. 70.

† *Ibid.* p. 71.

‡ *Ibid.* p. 70.

determine the positions of the spots on the sun's surface, in order later to study the changes in the solar phenomena in position and time; which had been the object of his observations from the beginning. To avoid this difficulty he adopted the method of projection, and continued using it for practically all his observations. It is only by this method, Scheiner remarks, that the appearance and positions of the spots can be accurately portrayed on paper, and thus only can the true and apparent motions of the spots be made ready for interpretation in an accurate manner. Another very essential advantage was that:*

> The observer gains such confidence in his manner of observing, and in the observations themselves, that every reason for doubt is removed.

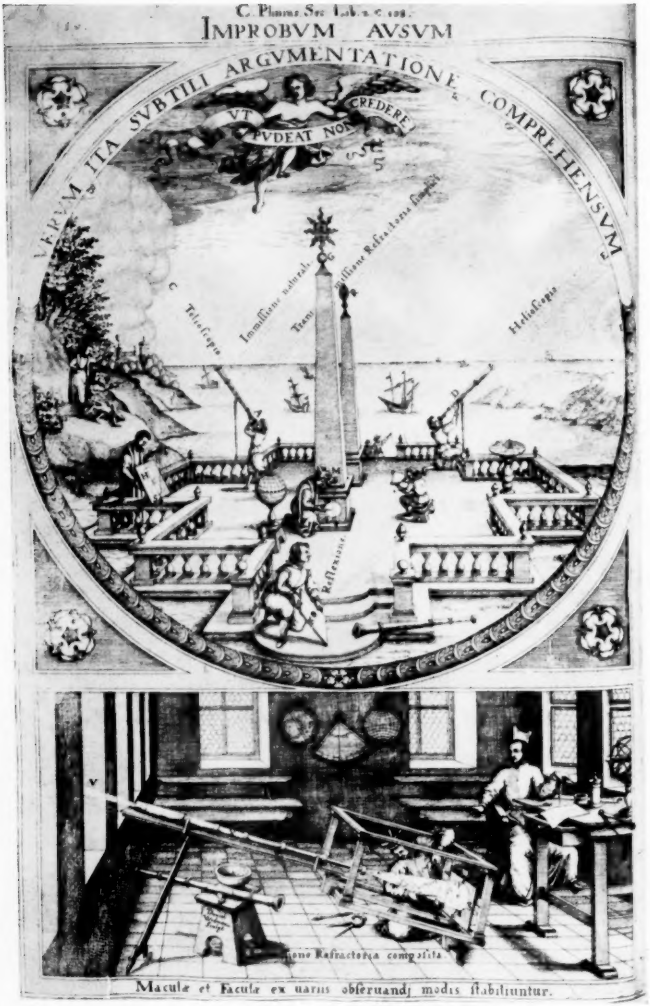
Scheiner apparently began using this method as early as 1612.†

From the conviction that the observer can be sure of his observations only when he knows his instrument thoroughly, or, as we say, when he knows its "errors", Scheiner undertook a most careful investigation to determine whether the positions of the spots obtained by the method of projection actually agreed with their true positions. To do this, he invented a device, which he believed to be most efficient and hitherto unknown‡ This device was used not only to establish the accuracy of the drawings but also for their measurement. He divided the circumference of a circle (smaller than the aperture of the telescope) drawn on a suitable card, into twelve parts, joining these points with straight lines in such a manner that there resulted a network of small squares formed by horizontal and vertical lines. The intersections of these lines with each other and with the circumference he punctured with a small needle; the card was then placed in front of the telescope objective. Directing the telescope toward the sun, the projected image showed small points of light which marked the position of each line. The punctures on the circumference were projected in a circle, but the straight lines, with the exception of the two diameters, were projected more or less curved. The displacements of these points could then be measured and later used to determine the corrections to be applied to the positions of the spots.

In order to observe successfully, the telescope must be provided with a suitable mounting capable of following the sun in its diurnal motion. This Scheiner originally accomplished by the construction of his "Machina Verticalis", which was essentially a form of alt-azimuth mounting. It was constructed somewhat as follows:¶ A strong frame-

* *Ibid.* p. 75.
† *Ibid.* p. 152.
‡ *Ibid.* p. 460.
¶ *Ibid.* p. 152.

PLATE XX.



FULL-PAGE ILLUSTRATION AT COMMENCEMENT OF BOOK III, *Rosa Ursina.*

work was supported in such a manner that one end was free to slide upon a smooth base. At the other end of this framework the telescope was mounted, at the end over the slide was placed a board to carry the paper screen upon which the image was projected. The full-page illustration at the commencement of the third book shows this arrangement, with the addition of a structure surrounding the board enabling it to be covered with a dark cloth, thus shading it from extraneous light. (Plate XX).

The obstacles met with in the pursuit of the observations, which Scheiner calls the "thorns of the Ursinian Rose" are described in the most detailed manner; he calls attention to every circumstance which might affect the accuracy of the observations. Great importance was placed on the correct orientation of the image, without which a comparison of the positions of the spots at different times, and the accurate determination of the rotation elements would have been impossible. The orientation of the image was obtained by allowing the shadow of a vertical thread to fall across the projected image. The points of intersection of this shadow with the circumference of the image were noted, as was the time, from which the sun's altitude could be calculated. This procedure yielded the necessary data for determining the orientation, since there was thus obtained the intersection of the vertical circle through the sun's center with the circumference of the disk, and a short calculation gave the position of the ecliptic on the projected image.

If one recalls the state of astronomical knowledge in Scheiner's day, one can easily understand that he should have placed great importance on this device, and would only communicate it to his friends as a precious secret. Micrometrical apparatus was still wanting, and in particular was excluded from use with the Galilean telescope. At that time there was no other method for determining the positions and motions of the spots which combined such great simplicity with such accuracy.

In spite of the commendable results which Scheiner obtained with this method of observing, in consequence of his dexterity and skill, he frequently complains of the difficulties encountered in making exact observations, which were mainly the result of the alt-azimuth form of mounting. However, the happy elimination of these difficulties was accomplished by another member of the Jesuit Order, Christopher Grienberger of Rome, who will be remembered as one of the four members of the Commission appointed to examine into Galileo's discoveries in 1611. Acting upon Grienberger's suggestion Scheiner

constructed what might be called the ancestor of the present day equatorial telescope. Concerning it Scheiner remarks:*

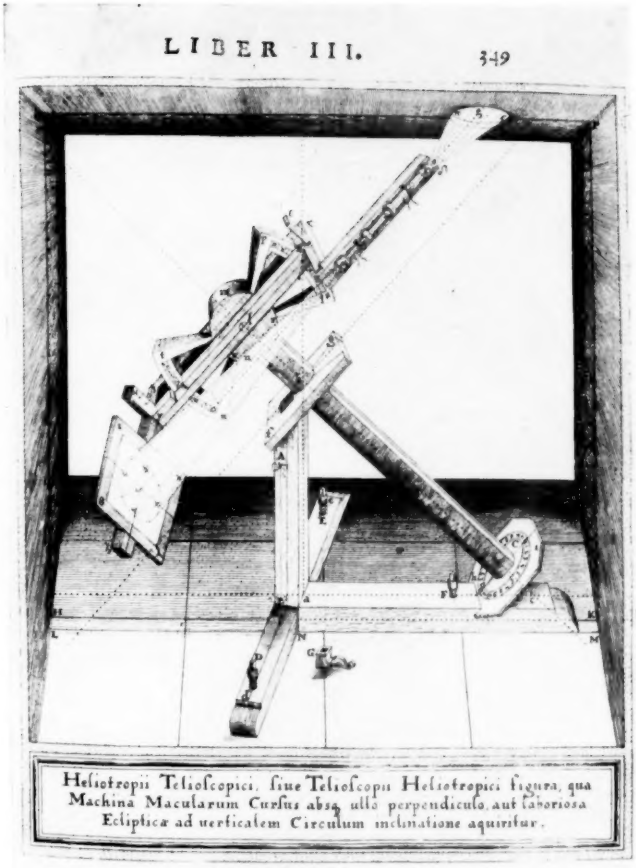
> The (equatorially mounted) telescope can be directed toward the stars,.....and when once directed toward the right parallel the telescope will always keep the star in the field of view. On this account the arrangement is very convenient for the day time observation of stars, since the position of the star can be found without fail, and Father Grienberger states that he had this particular thing in view while thinking upon this equatorial apparatus.

In the third book of the *Rosa Ursina* Scheiner gives a complete description of this instrument, "since it seems that the inventor has no desire to do so himself." The illustration in the *Rosa Ursina*† (Plate XXI) shows its essential characteristics. The instrument consisted of a polar axis of wood, provided with an hour circle; the telescope was mounted on this axis, the motion in declination, however, being limited to the extent of the zodiac. A scale of declinations was provided, but this was graduated with the signs of the zodiac instead of degrees. Barring the limited motion in declination, and the absence of a driving clock, this instrument was entirely similar in principle to our modern equatorials. Naturally Scheiner at once appreciated the advantages possessed by this instrument, and recognizing its convenience in observing and for following the sun's motion, called it "Heliotropii Telioscopici." He commenced using it on March 4th, 1627.‡ In addition to the convenience in following the motion of the sun, this mounting afforded the additional advantage of offering a much simpler and at the same time more accurate method of orientation of the drawings than did the earlier alt-azimuth mounting.

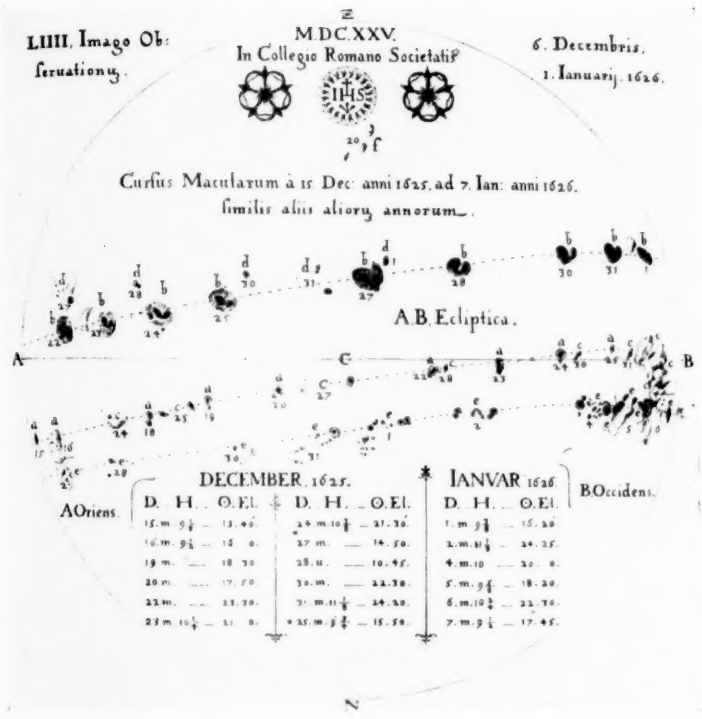
In addition to the description of the equatorial mounting, the third book of the *Rosa Ursina* contains the enormous mass of observational data obtained during the many years that Scheiner had devoted to the subject. It will be admitted by all, that none of Scheiner's contemporaries observed the sun's surface as industriously or as systematically. In order to obtain still more observational material he availed himself of the services of others who were associated with him in various ways. The foremost of these was Cysat, who was present at the time of the first observation, and afterwards succeeded Scheiner at Ingolstadt. After a time he added Father George Schönberger. To these two he communicated his valuable method of orienting the sun's image. Among the others who later assisted were Father Chrysostomus Gall, subsequently Professor of Mathematics at Lisbon; Father Giuseppi Biancani, Professor of Mathematics at Parma; Father Kasper Reuss, a missionary

* *Ibid.* p. 352.
† *Ibid.* p. 349.
‡ *Ibid.* p. 336.

PLATE XXI.


LIBER III.
349
Heliotropii Telioſcopici, ſiue Telioſcopii Heliotropici figura, qua Machina Macularum Curſus abſq; ullo perpendiculo, aut laboriosa Ecliptica ad uerticalem Circulum inclinatione aquiritur.

"HELIOTROPII TELIOSCOPICI."

PLATE XXII.

FULL-PAGE DRAWING OF SUN, SHOWING SPOTS AND FACULAE.

REDUCED FROM *Rosa Ursina*.

to Peru. It is of interest to note that the Hollander, Karl Malapert while on a journey to Poland, sojourned for a time at Ingolstadt in order to become acquainted with the methods of observing. By such means it was possible for Scheiner to obtain many uninterrupted series of observations from at home and abroad, which were well adapted for studying the rotational movement of the sun. Scheiner utilized these observations, which were made at widely separated stations to ascertain if there were any evidence of parallax shown by the spots; the results, as might be supposed, were negative.

In the *Rosa Ursina*, Scheiner published a large portion of his sun-spot observations, which were principally the observations made during his stay in Rome. Older observations, of equal importance, some of them made by Cysat, still remained at Niesse, from which place Scheiner had gone to Rome. But on account of wars and other dangers he dared not risk having them sent to him. As it is, there are seventy full page drawings of the sun (from December 1624 to June 1627), on each of which is shown the complete paths of various groups of spots and faculae during their period of visibility. The position of the ecliptic is shown on the drawings, as are the time of observation and the altitude of the sun. A mere glance at these drawings (see Plate XXII) is sufficient to show, to one familiar with the surface of the sun, the great accuracy and the conscientiousness shown by the portrayal of the smaller details. In 180 pages of the book is contained a very detailed journal of the observations describing the phenomena depicted in the drawings.

The fourth book contains a discussion of the results derived from the mass of observational data included in the third book,—the description of the phenomena of the sun's surface, and the theory of the spots and their motions. In an earlier part of his book, Scheiner had described the general appearance of the sun's surface as follows:*

> If one uses a helioscope of excellent quality, one sees in addition to these [the spots and faculae] the following unknown and hitherto unpublished phenomena: 1. That the entire surface of the visible hemisphere is varied, composed of shaded regions and points of light (luculae). 2. That the entire surface resembles a ruffled sea, and that this appearance continually changes.

Both Schreiber† and Carrara‡ assert that in the *Rosa Ursina* is given the first description of the phenomenon of the sun's surface known as the "granulation." This is believed to be an error. Galileo indicated in a letter to Gio. Battista Baliani, dated March 12, 1614, that

* *Ibid.* p. 71.
† *Op. Cit.* p. 78.
‡ *Op. Cit.* **24**, 91.

he had already observed this phenomenon. After stating his ignorance concerning the materials of which the sun-spots are composed, he writes:*

> It seems to me that I observe that all of the face of the sun is, so to speak, of heterogeneous light, that is, as if it were surrounded by a delicate cloud of unequal transparency.

This unquestionably refers to the granulation; and hence this was evidently first seen by Galileo, although Scheiner later described it more carefully and with greater detail.

Scheiner also described at some length certain phenomena of the sun's surface which leads one to believe that he had observed the so-called "veiled spots", to which Trouvelot called attention† in 1876. These Scheiner describes as follows:‡

> There are shadows or secondary spots, points of light (luculae) or secondary faculae, and regions of uniform brightness.....The duration of the individual shadows [veiled spots] and luculae, as well as of the uniform regions is short and very variable. For many shadows [veiled spots] endure for scarcely a day, not even for an hour, as can frequently be observed, for I have often devoted many hours exclusively to these observations.....I call these shadows "secondary spots" chiefly on account of their duration and faintness.....for these secondary spots are not real spots, as compared to the true spots, but with respect to the true spots are like a shadow to a solid body. In regard to size, appearance, position, faintness or darkness, and to total number these show a great difference. In the neighborhood of the pole they are very rarely noticed, in the spots zones they are very thin and faint, between these two regions they are numerous and prominent. They are seldom seen unaccompanied by luculae, which sometimes precede them, sometimes follow them, and are seen sometimes to the north or to the south, while sometimes they appear alone in the midst of a uniform region.

Scheiner considered the observations of the secondary spots and of the granulation to be of the greatest importance, also the most difficult of all the observations to accomplish satisfactorily. Notwithstanding this difficulty he devoted considerable time to it. He states:¶

> The secondary spots give the solar surface an appearance like a shining white cloth that has been covered with a cobweb, or like a piece of very clean paper that has been moistened, or like a well polished mirror that has been touched with the hand or breathed upon.

In another place he remarks:‖

> That which has been remarked for the secondary spots, holds similarly for the luculae, for they both are continually changing and present an almost incredible

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* *Gal. Op.* **12**, 34.
† *American Journal of Science*, (3), **11**, 165.
‡ *Rosa Ursina*, pp. 344-346.
¶ *Rosa Ursina*, p. 157.
‖ *Ibid.* p. 346.

transformation from one day to the next. One imagines the surface of a tranquil lake, or of a quiet sea disturbed by a gentle breeze and illuminated by the sun. The rippling presents a continual change of light and shade to the eye, as the sun's rays are reflected more or less. The same impression made by the rippled surface of the water is recalled by the above described appearance of the sun's surface.

It is evident from these quotations that Scheiner believed that the changes visible in the granulation actually took place as he observed them, and that the surface of the sun "rippled like a quiet lake." That such changes do take place is well known through the recent investigations of Hansky and Chevalier, but these could not have been observed by Scheiner. What he believed to be the real motions of the luculae were no doubt largely the effect of the disturbances in the atmosphere which produce the well known "boiling" effect.

The numerous observations which Scheiner made during so many years of patient industry naturally showed him the falsity of his former belief that the spots were of the nature of planetary bodies. How long Scheiner retained this belief is not known; at all events, the first acknowledgement that the spots were a part of the sun is in the *Rosa Ursina* (Lib. I). Galileo had recognized this soon after his first observations, although convincing proofs were not given until later, and explained the motion of the spots as caused by the sun's rotation. It is rather curious that Schreiber* will not give Galileo credit for ascertaining the true nature of the spots; he regards his conclusions as the fortuitous outcome of the intuition of a genius rather than a scientific result deduced from a series of carefully made observations. Schreiber considers it of greatest importance in judging the quarrel between Scheiner and Galileo, to remember that Galileo was unacquainted with the methods of determining the positions of the spots which had been developed by the Jesuit. The latter, it appears, laid little stress upon the question of who first saw the spots, but claimed credit because he had made the first scientifically valuable observations. But if we recall Scheiner's discussion of these "scientifically valuable" observations, and the erroneous conclusions that he drew from them, the laurel wreath will still be awarded to Galileo. Scheiner asserts in the preface to his *Rosa Ursina*† that during the years 1611 to 1617, no one but himself and his co-laborers at Ingolstadt knew how to make accurate sun-spot observations, and from such observations only could trustworthy conclusions be drawn. This is no doubt quite correct, but unfortunately Scheiner, although possessing the knowledge of a method of accurate observation, did not at that time know how to interpret his results correctly. In denying credit to Galileo, Schreiber asserts that up to

* *Op. Cit.* p. 84.
† *Ad Lectorem.*

the time when Galileo had made the first announcement of his belief in the solar nature of the spots and consequent rotation of the sun, he had not had sufficient opportunity to make a series of observations such as would be required for a conclusive demonstration of the published result. Schreiber also objects, because, since Galileo's observations were not made with sufficient care and accuracy to reveal the inclination of the sun's axis and the curvature of the spot paths, nothing else could have been deduced from them, and, hence, the correct theory of the spots announced by Galileo ought to be regarded as nothing more than a sort of happy guess, and not as a scientific result! Which, when one recalls the arguments in the letters to Welser, is a very peculiar view to take.

After Scheiner had persuaded himself that the spots must be adherent to the surface of the "rose of the Ursini," he pursued the subject with energy, and deduced proofs from his own observations. Concerning the solar nature of the spots as shown by their rotation, he writes:*

> 1. If the true, not the apparent motion shown by the solar phenomena is inherently regular, and if this regularity is conceded to it by the astronomers because of the apparent motion, and as a common sense interpretation of the observations; then this regularity is only possible if the spots are placed on the sun.....2. If the spots are placed on the sun, then their true and peculiar movement is always shown as regular.....3. If the spots are distant from the surface of the sun, then their true motion will never appear regular, but always as irregular and in contradiction to the apparent motion of the spots.

Galileo had announced as early as June 1612† that the regions in which the spots are found are limited to two zones on each side of the sun's equator. In the *Rosa Ursina*, Scheiner mentions these regions as follows:‡

> That region of the sun in which the primary spots are seen and describe their paths.....extends from both sides of the ecliptic (*sic*) toward the pole. Although one cannot fix a definite limit to this region, it appears, from observations made through many years, to extend not more than 30° toward the pole; but with respect to the faculae and the secondary spots the region sometimes reaches the pole.

Scheiner divides the remaining portions of each hemisphere into two zones, a truly polar zone and an intermediary zone. Concerning the phenomena visible in these three zones he remarks:

> The sun generally appears quiet in the polar zone, somewhat more active in the neighboring zone, and full of changes and mighty disturbances in the spot zone; although it can happen that the whole surface shines uniformly bright and illuminates us.

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* *Rosa Ursina*, p. 479, et seq.

† In the letter to Guiliano de' Medici; *Gal. Op.* **11**, 334.

‡ *Rosa Ursina* p. 568.

Scheiner gave considerable attention to the causes of, and the varying degrees of darkness shown by different spot nuclei. That he believed that the effect of contrast was for a large part responsible for the appearance of the spots is indicated. He writes:*

> Daily experience shows that objects of no great brightness, when between or near others which are very bright, cannot be clearly distinguished, and appear like shadows to our eyes.

Concerning the spots:

> The degree of darkness is very different, many are coal black, others are somewhat lighter or ash grey.
>
> What wonder is it if we see these bodies on the sun only in the color of shadows.....The truly black masses, however, I call the nucleus of the spot, for it is usually found in the middle of the spot.

Regarding the causes of the darkness, Scheiner conceived of two possibilities, either of which might give rise to this phenomenon; namely, an increase in the density, or an increase in the quantity of the material which formed the spot.† That increase in density alone could bring about the effect he considered as somewhat uncertain, for, as he argued, this could not change the color of the nucleus. As an illustration he mentions our atmosphere which is denser in winter and yet is actually more transparent.‡ On the other hand the observations offer no evidence of increase of material. If the spots become darker on this account, they must needs also increase in size from all directions. Conformably, the nucleus should grow fainter as the spots grow smaller. In addition may be mentioned the fact that the spots are darker in the center and brighter at the edges, a proof of the greater quantity of material at the center; if this were not so, the light would penetrate the center of the spots as it does the surrounding penumbra. In fact the phenomenon appears much more to favor some other physical cause than increase of similar material.

Scheiner then returns to the increase in density hypothesis, and reasons as follows: The nuclei are evidently not much below the level of their surroundings, for they can still be seen when entering and disappearing from the disk, but they are still sufficiently opaque to obstruct the passage of light more than the rest of the spot. If the dark nucleus is caused by the addition of material, the surrounding regions should become at least relatively darker, and the boundary between the nucleus and the penumbra would become relatively indistinct, which does not occur. On the other hand it must not be assumed that the nucleus increases from underneath to the same

* *Ibid.* p. 497 et seq.
† *Ibid.* p. 503 et seq.
‡ Scheiner's knowledge of meteorology was evidently deficient!

degree that the darkness increases. All this strongly favors the hypothesis of condensation or increase in density. This is further strengthened by the appearance of the nuclei of the small spots which are sometimes darker than those of other spots having larger area; it is also to be noted that these little spots last longer. Moreover the bright regions between the spots (bridges?) frequently consume the material surrounding the nucleus, which is not disturbed in any way; indicating a great difference between the nucleus and its surroundings.

(To be continued.)

DISCOVERY OF EIGHT VARIABLE STELLAR SPECTRA.*

HARLOW SHAPLEY.

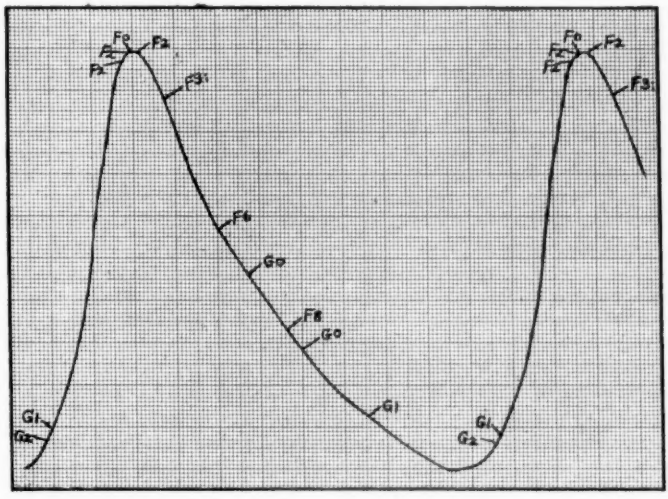
Mount Wilson Solar Observatory, Carnegie Institution of Washington.

In three earlier communications to the PROCEEDINGS various phases of the problem of Cepheid variation have been considered.† No further introduction to the present note is necessary beyond the statement that the periodic change in color, which appears to be typical of all Cepheids, has already been found to correspond to normal changes of spectral class for two cluster-type stars, RS Boötis and RR Lyrae, and for one variable of longer period, δ Cephei. In order to test to what extent the inconstancy of spectrum is a general phenomenon of Cepheids, some 150 spectrograms of representative variables of this class have been made with the 10-inch portrait lens and objective prism. The periods of the stars investigated range from 9 hours to 27 days; many are Cepheids for which spectroscopic orbits have been computed; some are well-known naked eye variables, others are much fainter stars; for some changes in color have been suspected from studies of the light curves, for others the maximum intensity of the spectrum has been observed to shift toward the blue upon the approach to maximum light. For none, however, has it been suggested, so far as the writer knows, that the spectrum changes periodically along the normal spectral series.

* Reprinted from the Proceedings of the N. A. S., for April 1916.

† Shapley and Shapley, 1, 452, 1915.
Shapley, 2, 132, 1915.
Adams and Shapley, 2, 136, 1916.

Following the numerical method of classification recently described by Adams,* the change of spectrum of the F-type and G-type Cepheids is susceptible to easy detection, even when the variation is very small. For example, in the work with low-dispersion on F-type spectra the relative intensity of the G band and the hydrogen line $H\gamma$ is particularly capable of showing small changes of type. The results can be summarized briefly.



THE LIGHT CURVE OF δ CEPHEI AND THE VARIATION OF SPECTRAL TYPE.

The accompanying figure contains a curve showing the spectrum variation for δ Cephei, exhibiting the conspicuous change, from maximum to minimum light, in the nature of the spectral lines. The detailed appearance with high dispersion of a small section of the spectrum has been shown in an earlier communication by Adams and Shapley. The table contains data relative to the spectra of eleven Cepheids, (all that are now known to vary in spectrum) and some information concerning their light variations. The observed range of spectrum variation is in nearly every case smaller than the total range, as observations at the exact times of maximum and minimum light were not made. All the variables for which the present test was sufficient were found to vary in spectrum. It appears safe to infer, therefore, that all the Cepheids (including the cluster-type), besides being variables in light and in velocity, vary periodically in spectral class as well.

* These PROCEEDINGS, 2, 143, 1916.

ELEVEN CEPHEIDS WITH VARIABLE SPECTRA.

Star	Maximum Magnitude	Range of Variation	Period	Number of Spectrograms	Observed Spectrum Variation
		Mag.	Days		
TU Cassiopeiae	7.3	1.1	2.139	9	F0 to F6
SU Cassiopeiae	5.9	0.4	1.950	19	A8 to F5
SZ Tauri	7.2	0.5	3.148	11	F4 to G2
T Monocerotis	6.0	0.8	27.012	6	F4 to F8
RT Aurigae	5.0	0.9	3.728	12	A8 to G0
W Geminorum	6.4	1.3	7.916	10	F3 to G0
RS Boötis	8.9	1.1	0.377	13	B8 to F0
X Sagittarii	4.4	0.6	7.012	5	F2 to G
Y Ophiuchi	6.2	0.8	17.121	4	F5 to G0
RR Lyrae	6.8	0.9	0.567	17	B9 to F2
δ Cephei	3.5	0.8	5.366	21	F2 to G3

STELLAR MAGNITUDES AND LIGHT RATIOS.

LOUIS BELL.

The translation of stellar magnitudes into light ratios and vice versa is one of the matters which frequently has to be dealt with in the photometric work which falls to the lot of the professional or amateur astronomer. As everybody knows, the relation between magnitude and light is a very simple one. A star of magnitude M gives 2.512 times as much light as a star of the magnitude M+1; or the star of M+1 gives 39.8% of the light received from the star of magnitude M. The light ratio and its inverse, the per cent relation, are ordinarily obtained with a logarithm table or, in observatories where the work is frequent, from a tabulation of the ratios, direct or inverse, belonging to each small difference of magnitude.

Having had considerable occasion to use in ordinary photometric work a photometric wedge graduated in stellar magnitudes, from which the light ratios had to be obtained, the writer turned to his slide rule and found readily the following method of making the computations, not in the least difficult, but rather outside the scope of the usual instruction book on the slide rule. For the simple geometric ratio of 2.512 per magnitude probably the easiest scheme of using the ordinary Mannheim slide rule, which has a cm scale along the unbevelled edge, is as follows:

Bring the fiducial mark on the runner down over its side by the careful use of a steel square, which enables one to take readings of the fiducial line on the cm scale. Then set the slide 1 cm to the left, so that its right hand index stands at 25 cm instead of 26, which is its usual position. Now taking each 5 cm as 1 stellar magnitude, one can read directly from the cm scale, which is actually divided to mm, the corresponding light ratios on scale B of the slide or the reverse. The graduation gives direct reading to .02 magnitude. In this way the ratios can be read quickly and accurately over a range of 5 magnitudes. Five magnitudes gives the ratio of 1 to 100, and the ratios beyond this magnitude difference go on repeating in an obvious manner.

If closer reading over a moderate range is desirable, as in looking into the light ratios of variables, take 10 cm per magnitude on the cm scale and read on scale C on the slide. This gives direct readings over a range of 2.5 magnitudes to hundredths of a magnitude. The inverse ratios can, of course, be obtained singly by taking the reciprocals in the ordinary way, but if it is desired to run them off directly it is only necessary to turn over the slide, setting the end indices in coincidence with those on the scales. The scale of equal parts in the center of the slide used for the purpose of reading off logarithms of numbers, then reads from right to left. Each of the numbered divisions is sub-divided into 50 parts and if one counts two of the numbered divisions per magnitude he has a scale extending over 5 magnitudes divided into hundredths, each small division on this scale being .5 mm. It is then only necessary to set off on this scale of equal parts the magnitudes to hundredths and to read the inverse ratio directly over scale A, (or counting 4 divisions per magnitude, on scale D). For instance, a setting at 2 on the scale of equal parts gives 39.8% for 1 magnitude, 15.8 for 2 magnitudes, and so on through the integral or fractional magnitudes up to 5. With the slide reversed in this way one can also read the direct ratios, just as from the cm scale with the slide displaced, but one has to read the scale on the slide either backwards or up side down in this case, which is rather less convenient than the scheme already described. This is really a very simple use of the facilities extended by the slide rule, but it is not immediately obvious, and the writer has found it a great convenience in reducing the readings on a photometer graduated in stellar magnitudes.

THE COSMOLOGICAL IDEAS OF THE GREEKS.

HECTOR MACPHERSON, M. A., F. R. A. S.

(I) The Speculative Period.

To the ancient Greeks belongs the honour of separating for the first time cosmology from theology. Just as the genius of the Hebrew people was religious, that of the Hellenes was in the direction of philosophy and art. And just as the Hebrews developed the religious view of the world, it fell to the Greeks to develop the philosophic view. As Eucken remarks—"Philosophy which in the case of the Greeks does not start from man and the problem of his happiness but from the Universe as a whole, aims to comprehend the world in a natural way by means of its own interconnections; it seeks for an immutable substance or for fixed quantitative relations. It is forced to discard the first impression of things and to destroy their visible image; but with a sure instinct for the essential it reconstructs the world in outlines whose simplicity bears the marks of genius and excites our perpetual wonder."

Nevertheless Greek cosmological speculation had its origin in the mythological age, and was at first similar to the mythologies of Babylon and other ancient lands. In the poems of Homer and Hesiod we meet with earlier Greek cosmological ideas; and in them cosmology and theology are, as in the Babylonian world-concept, inextricably connected.

Both Homer and Hesiod, in their poems, give us an idea of the world-view of the primitive Greeks. In Homer, the Earth is a flat circular disc, surrounded on all sides by the great river Okeanos. This mighty river commenced north of the Pillars of Heracles, and wound its way north, east and south of the Earth. The disc of the Earth is supposed to be partly covered with the sea. South-west of the River Okeanos is the land of the Cimmerians; and, in some places, Homer indicates that adjacent to the Cimmerian land is Erebus or the land of the shades; in other passages, however, Homer places Hades beneath the surface of the Earth.

Above the Earth is the region of the ether; and still higher is the vault of the heaven. Beneath this vault the Sun, Moon and stars perform their motions, rising out of Okeanos in the morning and returning thither at night. The Hesiodic conception is somewhat similar. Hesiod places Tarturus, "the depth", as far below the Earth as the height of heaven is above. Thus the whole Universe is represented as a sphere.

And this sphere is divided into two halves by the earth's surface. This conception is somewhat akin to that of the Hebrews, as brought out by Schiaparelli. In his "Theogony" Hesiod puts forth his cosmogonic views. How far this work is the product of purely Hellenic thought is uncertain. Pfleiderer considers that the work "in many instances disarranged popular legends with foreign Asiatic speculation." In the beginning was Chaos, from which sprang the Earth-goddess, Gaia, the mother of all. Then follow Erebus and Aether, and these are followed by the production of Uranos, the god of the heaven, and from the union of the god of heaven and Gaia, the goddess of earth, there springs the race of gods and titans—personifications for the most part of natural forces. The only important point about the theogony is the fact that the Earth sprang from Chaos, and from the union of Earth and Heaven the other personified natural forces were produced.

What Hesiod actually meant by Chaos is uncertain. Plutarch believed it to be water; and in one or two places, Homer speaks of Okeanos as the origin of everything. Here we have the connection of Greek and Babylonian mythology as Dr. Dreyer notes "the connecting link between the primitive popular notions and the first attempt at philosophical enquiry."

This first attempt was due to Thales of Miletus, the first Greek philosopher. It is true that his idea of the constitution of the world was as primitive and, in the light of later knowledge, as absurd as those of Homer and Hesiod. The Earth, he believed, was a circular disc floating like a piece of wood on the ocean; and in water Thales found the ultimate principles or substance of the world. At first sight, Thales may appear to have advanced but little beyond the standpoint of the poets; but there is one essential difference between his explanation of the world and theirs. Thales separated cosmological from religious speculation. In his explanation of the Universe, there was no mythological element. No gods or godesses were invoked—as in the cosmology of Hesiod and in the Creation Epic of the Babylonians. Aristotle discussing Thales' belief in water as the "first principle" suggests that the Milesian philosopher got the idea "because he saw that the nourishment of all beings is moist and that heat itself is generated from moisture, and persists in it (for that from which all things spring is the first principle of them) and getting this idea also from the fact that the germs of all beings are of a moist nature." Thales, at all events, has the distinction of being the first scientific philosopher.

Anaximander, the second philosopher of the Ionian School, abandoned the view of Thales. He found the first principle not in water nor in any other substance, but in the infinite (το ἄπειρον) or the indefinite.

This, says Schwegel, "was not something immaterial, but was probably conceived by Anaximander as primal matter not yet sundered into its individual elements." Out of this are all things developed and into it all things return. This conception of the origin of things was a remarkable one, and the sagacity of Anaximander's cosmogony is a strange contrast to the crudity of his world-view. He believed the earth to be flat or convex on the surface and to be in equilibrium in the center of the world. The heavens, he considered, were of the nature of fire and spherical in form. The heavenly bodies were thought to be placed at different distances—the Sun being more distant than the fixed stars. He had a curious explanation of the nature of the heavenly bodies. The Sun was a hole in a great ring through which the inhabitants of the Earth got a view of the fire which filled the rim of the ring, while the Moon and stars were similarly explained.

Anaximenes, the third of the Ionian philosophers, was if anything less advanced than the second. He found the "first principle" in air out of which all things were formed by compression or rarefaction; thus the Earth was produced from dense air. Anaximenes believed the Earth to be flat and the Sun, Moon and planets to be also flat bodies, while he supposed the stars to be attached like nails to a solid vault.

The Ionian School did not advance very far in the explanation of the world. At the other end of the Greek world, however, another school of thinkers—the Eleatics—had arisen and they developed more advanced views. Xenophanes, the founder of the school, it is true, did not advance beyond the Ionian standpoint. The Earth he believed to be flat and "rooted in the infinite," while the Sun, comets and stars were supposed to be fiery clouds. The Sun and stars were formed daily from fiery particles while the Moon was a compressed cloud which shone by inherent light and was extinguished monthly. Parmenides, the virtual founder of the Eleatic school, was a much more profound thinker. To him belongs the distinction of perceiving the spherical form of the Earth—a great advance in thought; he considered the entire universe to consist of a number of concentric layers encircling the stationary earth. This is the first time, as Dr. Dreyer observes, that we meet with the conception of concentric spheres. Parmenides also noticed that the Moon appears "always gazing earnestly towards the rays of the Sun and he drew the correct deduction that it shines by reflected light. He considered the Sun and Moon to consist of materials detached from the Milky Way, and the stars to be nearer to the Earth than the Sun, an error similar to that of Anaximander.

Curiously enough Heracleitus of Ephesus, who was a thinker at least as profound as Parmenides was much less happy in his cosmological speculations. Heracleitus found the explanation of the world

in universal flux,—"Becoming" "All things flow" (πανὰ ῥει). Accordingly he was led to consider fire to be the "first principle" of the world. There is, he taught, an unending circulation in nature "upward, downward, the way is one and the same." Accordingly it was in keeping with the doctrine of flux to revert to the idea of a flat earth. The Sun he believed to be formed of moist exhalations caught in a hollow basin with its cavity facing the Earth. The orb of day was ignited every morning and extinguished every night. On the whole Heracleitus' cosmological speculations marked not an advance but a retrogression in thought. Indeed the marvellous intuition of Parmenides seems to have been completely overlooked. Such illustrious thinkers as Anaxagoras, Empedocles Leucippus and Democritus erred fundamentally in regard to the shape of the Earth.

Anaxagoras believed that mind (νους) had produced the world out of the original chaos—the most profound idea of the ultimate cause of the Universe put forward before Plato and Aristotle. Mind formed the world by starting a rotatory movement, by which the present state of things was produced. Matter was thus separated into two halves, ether and air. The air—cold, dark, and heavy—was agglomerated in the centre, and from this was produced water from which again Earth appeared. The Earth was considered to be flat, and the Sun and Moon were supposed to be composed of similar matter—a considerable advance in thought. Anaxagoras also held the somewhat absurd view that the Milky Way represented the shadow of the Earth.

Empedocles,—working from his idea of four primary elements fire, air, water and earth, swayed to and fro by love and hate, attraction and repulsion—believed the Universe to be spherical and the earth to be flat. The Moon he considered to be air rolled together and mixed with fire and illuminated by the rays of the Sun, which was itself "a reflection of the fire surrounding the Earth."

Leucippus and Democritus were the first exponents, in rudimentary fashion no doubt, of scientific materialism. Leucippus believed matter to consist of an infinite number of atoms, very small and indivisible, by the union and separation of which the world is caused. Democritus believed that as a result of collisions among the atoms themselves a vortex motion resulted. Thus an infinite number of worlds is formed and thus the Earth originated. The Earth, according to Leucippus, is flat on the surface with an elevated rim. Democritus considered the Earth on the other hand to be a *discus*, higher at the circumference and lower in the middle. The Sun and Moon were considered to be large and solid masses. In regard to the Moon and to the Milky Way, Democritus held views in advance of his time. He believed the lunar markings to be due to the shadows of mountains and valleys; and he

propounded the view that the Milky Way was an appearance due to the combined light of many faint stars.

More influential than the Ionian or the Eleatic Schools or than the followers of Heracleitus and Democritus was the famous Pythagorean Brotherhood. The philosophical school of Pythagoras was not only devoted to science and philosophy; it was also a religious society and a political organization. Hence it occupies a somewhat unique place in the history of Greek thought.

The underlying idea of Pythagoras was that the explanation of everything is to be sought in number. In the clear words of Dr. Dreyer, Pythagoras believed "that number not merely represents the relations of the phenomena to each other but is the substance of things, the cause of every phenomenon of nature. Pythagoras and his followers were led to this assumption by perceiving how everything in nature is governed by numerical relations, how the celestial motions are performed with regularity and how the harmony of musical sounds depends on regular intervals the numerical valuation of which they were the first to determine." Amid a great deal of fantastic speculation, Pythagoras seems to have got hold of various aspects of truth. To him, the universe was a sphere; and at its centre was the Earth, also of a spherical figure. This view, held by Parmenides alone outside of the Pythagorean School, was now accepted by the disciples of the founder.

The Pythagoreans latterly advanced beyond their master's cosmological standpoint. Philolaus taught that the apparent rotation of the starry sphere and the motion of the Sun around the Earth are caused by the movement of the earth in twenty-four hours round the circumference of a circle. This idea incorrect though it was marks a real advance in scientific thought. Philolaus went a step further. He considered that the Earth could not be the center of the Universe, but that the earth and the other celestial bodies moved round the "Central Fire" or the "Hearth of the Universe." This body, Philolaus and his followers held to be invisible from Greece and only to be seen in the regions beyond India. This doctrine called forth the ridicule of Aristotle. "They forcibly make" he said "the phenomena fit their opinions and preconceived notions and attempt to construct the Universe."

In many ways the Pythagoreans deserved the ridicule of the great philosopher. For instance as ten was supposed to be a perfect number, it was necessary to assume the existence of ten celestial bodies. Only nine were known—the earth, the Sun, the Moon, the five planets and the sphere of the fixed stars. Therefore the Pythagoreans imagined the existence of another body—the "antichthon" or "counter-earth" perpetually invisible from the inhabited side of our planet's surface.

Yet with all their errors the Pythagorean School under Philolaus took a remarkable step. They boldly declared that the chief place in the Universe was not occupied by our world. Hicetas of Syracuse seems to have gone still further and anticipated, partially, the Copernican system. Cicero writing long afterwards said that "Hicetas of Syracuse, according to Theophrastus, believes that the heavens, the Sun, Moon, stars and all heavenly bodies, are standing still and that nothing in the universe is moving except the earth, which while it turns and twists itself with the greatest velocity round its axis, produces all the same phenomena, as if the heavens were moved and the Earth were standing still." Opposition was developed within the Pythagorian School not only to this notion but also to that of Philolaus. Both Philolaus and Hicetas were in advance of their time and their views were destined to meet with but little approval.

In one particular the Pythagorean School did not teach in vain. The doctrine of the spherical form of the Earth was never again seriously challenged by intelligent men. The Pythagorean school had in itself a wide influence, but it exerted a still wider influence through the greatest of ancient philosophers, and one of the greatest minds of all ages—Plato. On the whole Plato had little interest in natural science. He had inherited from his master Socrates his somewhat contemptuous attitude to the observational study of nature. According to Xenophon, Socrates considered a knowledge of astronomy useful in so far as it enabled determinations of the days and hours to be made; but such questions as the orbits and distances of planets and stars and the causes of their revolutions, he considered to be a waste of time. Plato, like his master Socrates, was neither an astronomer, nor a mathematician nor a physicist. Nevertheless he was destined on account of his far-reaching influence to have a profound effect on cosmological thought. In the *Timaeus*, Plato explains that the Deity made the Universe and that he made it of a spherical shape, with one motion, that of rotation on its axis. After his exposition of his ideas regarding the "soul of the Universe," Plato explains that God resolved to form a movable image of eternity on the principle of numbers, which is time. "With this design the Deity created the Sun, Moon and the five other stars which are called planets, to fix and maintain the numbers of time." A good deal of controversy has raged over certain obscure passages. Some scholars consider that Plato believed in the rotation of the Earth about its axis and that he was actually a follower of Philolaus. But on the whole the balance of evidence is against the contention that he held such views. There seems no reason to doubt that he believed the Earth to be the centre of the Universe, a sphere suspended in space, fixed and immovable at the center of creation.

In regard to the heavenly bodies, Plato considered that the stars, chiefly formed of fire, move through the ether, a particularly pure form of air, which reaches from the limit of the terrestrial atmosphere into the starry spaces. The moon he believed to be the nearest body to the Earth; and in virtue of its proximity it resembled the Earth more than did the other celestial bodies. He believed it to be dark, shining by reflected sunlight.

On the whole, it must be admitted that, great thinker though Plato undoubtedly was, stupendous as was his intellect, he played a very unimportant part in the history of cosmological thought. At the same time, there is no doubt that Plato did a great deal to popularize the notion of the spherical form of the Earth. His books had a wide circulation in the ancient world, and his opinion carried extraordinary weight. By the time of Plato's death therefore, the fact of the spherical form was accepted on all hands.

(II) The Practical Period.

With Eudoxus of Cnidus, the cosmology of the Greeks entered on a new phase. With all his limitations, Eudoxus may be described as the first investigator of cosmological problems from a purely scientific standpoint. The changed outlook may be realized when we compare the methods of the previous thinkers with that of Eudoxus. The earlier philosophers had proceeded on the grounds of reason alone. Their method was deductive. Eudoxus on the other hand, was on the whole an inductive thinker. He was an observer of the phenomena of the heavens and to explain these phenomena, he advanced his famous theory of the homocentric spheres. Whether the theory was ever more to him than a convenient working hypothesis is uncertain. Dr. Dreyer, who has made a close study of the Eudoxian theory, believes that Eudoxus only regarded his spheres as "geometrical constructions suitable for computing the apparent paths of the planets."

The system was a very complicated one, but a brief sketch will suffice to explain its general nature. The Earth of course was believed to be spherical, occupying the center of the Universe and each celestial body was believed to be situated on the equator of a sphere revolving with uniform velocity around its poles. But Eudoxus, by observation of the heavens, was aware of the irregularities—retrogressions, variable velocities and stationary points—of the planets, and so it was necessary to postulate the existence of other spheres. The poles of each planetary sphere were believed to be attached to larger spheres, concentric with the others rotating round different poles with varying velocities. These poles of the second spheres were themselves rotating round other and still larger spheres. For the Sun and Moon Eudoxus found three

spheres each sufficient, but in order to explain the complicated motions of the planets it was necessary to assume the existence of four spheres for each. For the fixed stars of course one sphere was sufficient. Finally Eudoxus had to assume the existence of twenty-seven spheres in all. On the whole, the theory, complicated and cumbersome though it was, accounted fairly well for the observed celestial motions. It explained the motions of all the planets, except Venus and Mars, but this is not to be wondered at, considering the insufficient observational data on which Eudoxus was compelled to work. Thirty years after the theory was first propounded, it was improved by Calippus, a pupil of Eudoxus, who is also known for his improvement on the Metonic cycle. Calippus considerably altered the system by adding a number of extra spheres to explain irregularities which had either escaped the notice of Eudoxus or which had been ignored.

The theory of homocentric spheres, as it is generally called, seems cumbersome, if not fantastic in the light of present-day knowledge, but viewed in its true light it marks an era in cosmological speculation. It was the first attempt to account for the observed phenomena of the Universe. Eudoxus was not a philosopher; he was first and foremost a mathematician and man of science and his theory was framed to explain observed facts. Indeed, as already mentioned, to him it may have been a convenient working hypothesis and nothing more.

If the theory was merely a theory to both Eudoxus and Calippus, it was a great deal more to Aristotle. In fact, it formed the basis of that great philosopher's cosmological conceptions, which exercised so profound an influence over human thought not only in his own day but throughout the post-classical period and the Middle Ages. When we realize the range of Aristotle's researches and his deservedly great reputation as philosopher and moralist, we are enabled to understand, partly at least, the reason of his long supremacy over the minds of men.

The natural philosophy of Aristotle was expounded in the eight books of his work on "Physics", in his four books on "The Heavens", and his four books on "Meteorologica." In the first of his books on "The Heavens" he argues that the material universe cannot be extended indefinitely in space, since a line drawn from the center of our Earth to a body indefinitely distant could not perform a motion of rotation in twenty-four hours. If the Aristotelian Universe was not infinite, however, it was regarded as eternal. In his cosmical speculations Aristotle was largely guided by his philosophical ideas. He adopted the view of Eudoxus as to the spherical shape of the Universe. On the ground that the sphere is among bodies the most perfect. In the

spherical cosmos the most perfect sphere is that with the most perfect motion; and as the swiftest sphere is the most perfect in motion, the outermost is the most perfect of all. The entire argument is purely speculative and the outlook of Aristotle on the ultimate problem of the Universe contrasts strangely with the scientific procedure of Eudoxus, whose cosmological hypothesis he adopted. To Aristotle the spheres were actually in existence, portions of the vast mechanism of the Universe. He found it necessary—in order to explain why the motion of the outer spheres was not shared by the inner in spite of their connection—to add twenty-two extra spheres. Callipus had assumed the existence of thirty-three, so that as left by Aristotle, the system comprised fifty-five separate spheres.

Aristotle devoted considerable attention to the form of the Earth, its position in the Universe, and its possible motion. Aristotle bases his belief in the spherical shape of the Earth on both theoretical and empirical considerations. The former are of little account, but the latter are of more permanent value. He notes firstly the fact that the shadow thrown by the Earth on the Moon is always circular, showing that the Earth must be a sphere; and secondly, a journey north or south changes the apparent positions of the stars. He mentions the Pythagorean view that not the Earth but a central fire occupies the centre of the Universe; but this theory he rejects in favor of the view that the Earth is fixed and immovable in the centre of creation; and he does not seem to have been acquainted with the view of a rotation of the Earth on its axis.

Aristotle is careful to distinguish between the heavens, the region of unchangeable order where circular motion prevails, and the region below the lunar sphere in which are placed the four elements, earth, water, air and fire. The ether he believes to become increasingly pure at greater distances from the Earth's surface; and in the upper atmosphere comets and meteors and aurorae were believed to be produced. He also believed the Milky Way to be an atmospheric phenomenon.

After all the cosmological ideas of Aristotle do not seem to be very far in advance of those of earlier thinkers; and indeed in some instances his opinions were decidedly reactionary. There is therefore a natural temptation to ask why the opinions of Aristotle on cosmology should have so great weight in later years. The answer is to be found in the unique position occupied by Aristotle in the history of thought. He was not merely an astronomical or scientific thinker, or a great mathematician. He was the most commanding figure of his age and in him, so to speak, was summed up the scientific and philosophic culture of the Hellenic world. Thus the pronouncements of Aristotle, even in the Hellenistic period, were invested with peculiar authority.

We find, for instance, that among men of philosophic or scientific mind, the spherical form of the Earth was never again seriously disputed; while the erroneous doctrine of the fixity of the world in the centre of the Creation was invested with all the authority of the greatest of philosophers.

Yet, almost contemporary with Aristotle, there were two distinguished Greeks who seem to have grasped the truth in regard to the Earth's place in Nature. Heracleides of Pontus was a pupil of Aristotle, but appears to have had the courage to think for himself on the system of the world. In the words of the commentator Simplicius "Heracleides of Pontus, assuming the Earth to be in the middle and to move in a circle, but the heavens to be at rest, considered the phenomena to be accounted for." Actius, another ancient writer, remarks that Heracleides considered the Earth to move "not progressively, but in a turning manner, like a wheel fitted with an axis, from west to east, round its own centre." In other words, Heracleides believed that the Earth turned on its axis in twenty-four hours and thus explained the apparent motion of the sphere of the fixed stars. Another forward step was taken by Aristarchus of Samos, who boldly declared that instead of the Sun moving round the Earth, our world travelled round the Sun. "He supposes", said his contemporary Archimedes, "that the fixed stars and the Sun are immovable but that the Earth is carried round the Sun in a circle." His brilliant intuition, however, was destined to obscurity. It did not harmonize with the opinions of Aristotle and the authority of the great philosopher was supreme. Besides, even in those Pagan days, the heliocentric theory was considered a dangerous doctrine. According to Plutarch, "Cleanthes held that Aristarchus of Samos ought to be accused of impiety for moving the hearth of the world, as the man, in order to save the phenomena, supposed that the heavens stand still and the Earth moves in an oblique circle at the same time as it turns round its axis." Aristarchus was the last thinker of the Greek world who strove to find the physically true system of the Universe. The theories which followed were merely mathematical hypotheses representing the motions—regular and irregular—of the various planets.

It is somewhat remarkable that while more and more stress was laid on Aristotle's opinion as to the immobility of the Earth, the astronomical theory on which he based his hypothesis—the spheres of Eudoxus—was soon discarded. The rise of practical astronomy, by demonstrating its inadequacy hastened its rejection. The necessity of regulating time, the need for an accurate calendar, had stimulated observation of the Sun and Moon and this in turn influenced other branches of astronomy. At Alexandria, under the patronage of the

dynasty of the Ptolemies a school of astronomy was founded and systematic observation of the heavenly bodies was made. As Dr. Dreyer has well remarked, "Vague doctrines and generalizations were abandoned, while mathematical reasoning founded on observation took their place. That this change occurred about the middle of the third century was a circumstance not unconnected with the simultaneous rise of the School of Stoic philosophy. Both in abstract philosophy and in science the wish to get on more solid ground now became universal and no science benefited more by this realistic tendency than astronomy."

To Apollonius of Perge is due the distinction of inventing the famous theory of epicycles which superceded the spheres of Eudoxus. After using for some time the so-called theory of "excentric circles," Apollonius put forward the theory of epicyclic motion. The idea of concentric spheres was abandoned; Sun, Moon and stars were assumed to be in motion round the Earth in circular orbits; but some explanation had to be given of the irregularities of the celestial motions. In essence, the systems of Apollonius, Hipparchus and Ptolemy were identical, but the latter scientist worked the epicyclic theory to its fullest perfection.

The epicyclic theory is not easy of explanation and we cannot do better than reproduce the exposition given by Sir Robert Ball in his sketch of Ptolemy. He takes the typical case of Mars with its irregular motion. "We have the Earth at the centre and the Sun describing its circular orbit around that centre. The path of Mars is taken as exterior to that of the Sun. We are to suppose that at a point M there is a fictitious planet which revolves around the Earth uniformly in a circle called the deferent. This point (M) which is thus animated by a perfect movement is the centre of a circle which is carried onwards with M and around the circumference of which Mars revolves uniformly. It is easy to show that the combined effect of these two perfect movements is to produce exactly that displacement of Mars which observation discloses."

This is a sketch of the theory at its simplest, but it is sufficient to illustrate its general principle. As astronomical observation progressed, new irregularities were discovered and had to be accounted for. Hipparchus of Rhodes will ever hold the chief place among the astronomers of antiquity. Not only did he form a catalogue of stars, and thus lay the foundations of practical astronomy, not only did he discover the precession of the equinoxes, but he succeeded in working out solar and lunar theories. He did not satisfactorily explain the motions of the planets on the epicyclic theory, and in fact he merely accepted the epicyclic theory, as a convenient working hypothesis.

In Ptolemy of Alexandria, who lived three hundred years after Hipparchus, ancient science reached its culmination. In his great work

the *Syntaxis* commonly known as the *Almagest*, he develops the theory to its fullest extent. In the first book of his great work, he demonstrates that the Earth is a sphere fixed and immovable in the centre of creation, and the heavens is also a sphere, rotating in twenty-four hours round an axis. This is the fundamental assumption of the Aristotelian philosophy and Ptolemy accepted it. He worked out carefully the epicyclic theory in the light of the discovery of new irregularities in the celestial motions, and as a result a number of extra circles and epicycles had to be introduced.

Like Eudoxus and Calippus, Apollonius and Hipparchus, Ptolemy does not seem to have troubled as to the actual physical truth of his system. "I do not," he said, "profess to be able thus to account for all the motions at the same time; but I shall show that each by itself is well explained by its proper hypothesis." If to Ptolemy the theory was merely a working hypothesis, it was soon regarded by the intellectual world at large as the true system of the world. The philosophy of Aristotle and the science of Hipparchus and Ptolemy was the last word of ancient cosmological thought; and during the Middle Ages the word of these masters was final.

In the Hellenistic period—after Aristotle and Plato—men do not seem to have troubled over purely cosmogonic problems. There was little speculation as to how the world came to be. The Stoic School in so far as it concerned itself over such matters followed Aristotle. The pantheistic nature of the Stoic philosophy led these thinkers to the doctrine of an all-pervading primary substance co-extensive with matter. This primary substance identified by Cleanthes with fire, was generally regarded as one with the Deity. Thus the Stoic cosmogony resulted in pantheism.

The atomist school, represented among post-Socratic thinkers by the Epicureans, found its leading exponent in the Roman poet Lucretius. On the whole, Lucretius is not original; he merely reproduces the ruling ideas of Leucippus and Democritus. He pictures the concourse of atoms in indescribable confusion at the beginning of time. "At last the parts began to fly asunder, and like to join to like and mark off the members of the world and every one of its mighty parts—to separate high heaven from earth and let the sea spread itself out apart, and also let the fires of the ether spread apart, pure and unmixed." We cannot but be impressed with the retrogression illustrated by the cosmological fancies of Lucretius; and thus, he counts for little in the history of cosmology.

Hellenic culture had exhausted itself at the beginning of the Christian era; and although it lingered on for some centuries, it counted for little in the world's thought. When the Emperor Justinian suppressed the Neoplatonist Schools in 529 he merely gave legal expression to an accomplished fact. The long night of the Middle Ages had begun.

THE THEODOLITE FOR TESTING TELESCOPIC SPECULA.

A new use for a familiar instrument.

RUSSELL W. PORTER.

It is a well known fact among amateurs who are attempting their own reflecting telescopes, that when the stage in making the concave mirror is reached where the surface changes from a sphere to a paraboloid, a somewhat precise tool must be provided whereby the different foci found in the neighborhood of the center of curvature, may be located and measured: and that these positions, all lying along the axis of the mirror, and within a few tenths of an inch of each other, must be determined within an error of the order of 1/100 inch.

Home made affairs will not, as a rule, stand up under this degree of accuracy, and, in casting about for the right device, the writer found that the theodolite, or ordinary surveyor's transit might be so used as to provide an almost ideal instrument in the laboratory tests of specula.

The transit is set up on a firm stand with its vertical axis at about the distance from the glass equal to its radius of curvature, with two of its leveling screws parallel, and the telescope tube at right angles, to the axis of the mirror. A piece of tin foil is glued over the opening in the diagonal eyepiece of the telescope, and a pinhole formed by puncturing with a needle. A lamp at a convenient distance throws light down the telescope tube to the pinhole, and the arrangement is ready for use.

It so happens that the outer edge of the prismatic eyepiece provides the knife edge, and posesses the great advantage of being very close to the pin hole. The action of the instrument is then as follows.

Having so adjusted the speculum on its stand, that it returns the light to a point just outside the knife edge, the observer returns to the transit and, by means of the leveling screw farthest away from the pin hole, brings the knife edge up to and in interference with the reflected cone of light. If the reflected image is not in the same horizontal line with the pin hole, it may be made so by depressing that end of the telescope with the telescope tangent screw.

The horizontal tangent screw may now be used to bring the knife edge to any desired focus, and the difference of the readings of the horizontal circle, in arc, will give the relative positions of the various foci.

To obtain the absolute measures of these distances, find the horizontal distance of the knife edge from the vertical axis of the instrument, and call it R. Let a and a' be the horizontal circle readings of any two foci. Then

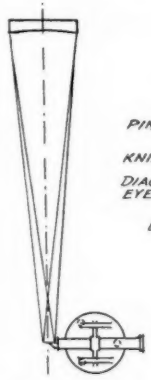
$$a' - a$$

will be the angle through which the knife edge has swung in passing from one focus to the other, and

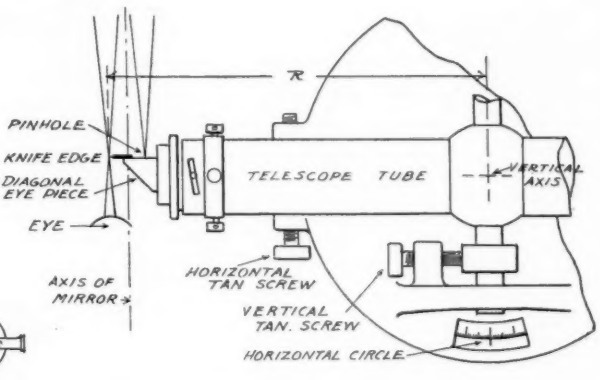
$$R \sin (a' - a)$$

will be the distance between them, nearly.

The accompanying diagram will make clear the above description.



MIRROR AND THEODOLITE.



ENLARGED VIEW SHOWING PARTS OF THEODOLITE USED IN TESTING MIRRORS

One or two other points may be noticed. If the tests are to be conducted with an immovable light source, the artificial star may come from a separate stand, and the foci found and measured as above, with the theodolite. By attaching an eyepiece to the telescope close to the knife edge, the image of the pinhole may be examined both in and out of focus, by use of the horizontal tangent screw. This virtually makes a telescopic focusing rack out of the transit, but an extremely sensitive one with a scale (the horizontal circle) attached.

This adaptatation of the alt-azimuth instrument only emphasizes its former reputation of being a universal instrument, and, where available, such as in institutions likely to possess valuable mirrors, furnishes a ready and accurate means of verifying their optical properties.

Land's End, Port Clyde, Maine.

January, 1916.

THE PARTIAL SOLAR ECLIPSE OF FEBRUARY 3, 1916.

G. L. HARRELL.

The partial eclipse of the sun on February 3, 1916 was observed at the James Observatory under the most favorable conditions. On January 31, it rained and the ground was covered with sleet and snow on February 1, but February 2 dawned calm and clear and the same was the condition on the morning of February 3. The sky was perfectly clear as it always is after a good rain, there was no wind and the temperature the night before was recorded at 19 degrees above zero, the lowest for the winter.

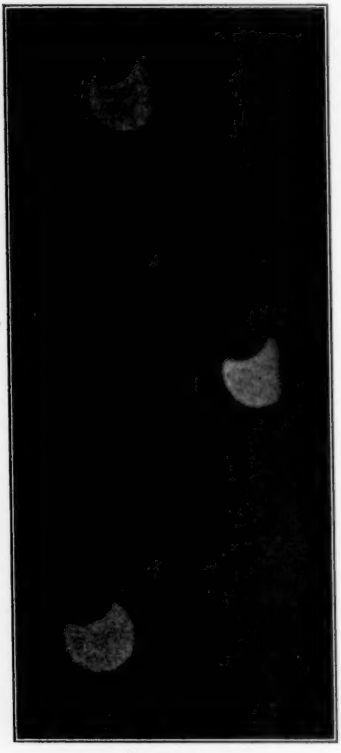


FIGURE 1.
Partial Eclipse of Sun, Feb. 3, 1916.

The time for first contact had been computed for our position as 8^h 35^m a. m. Central Standard Time. Promptly on the minute the moon began to encroach upon the face of the sun and continued its journey thereon until 10^h $43^m.18$ at which instant the last contact was observed. About 27 per cent of the sun's diameter was obscured. Just before the last contact the writer removed his eye from the telescope long enough to look through a smoked glass to determine how long the naked eye might see the sun in eclipse. It was seen with the smoked glass fifty-six seconds before the last contact was observed with the telescope. No later effort was made to see it with the naked eye for fear of losing the final contact with the lens.

The class in astronomy met at the observatory at an earlier hour on that morning that they might see the eclipse. Of course there was nothing out of the ordinary to be observed, and the only interest, to them, was the novelty of seeing an eclipse through the telescope.

The photograph was made with a 3½″ portrait lens (E. Suter Aplanat B No. 7) and is enlarged two times. Three exposures were made upon the same plate which was a Stanley Sensitometer 50.

The developing, printing, and enlarging were done by the Daniel Studio, the leading photographer of our city. It was through the courtesy of the same establishment that we had the use of the portrait lens. The shaded phase on the limb of the sun was produced by the edge of the opening in the dome. The camera was preceding the tube and was thrown into the shadow before it was noticed otherwise.

No preparation had been made to make the photograph of the eclipse as the camera was used for work at night on other objects. There was an unused plate and the writer exposed it to see how well the small lens would do in such work.

The writer will not end what he has to say in regard to this eclipse without making a few statements in regard to the total eclipse of 1918 June 8. Some time ago he made some computation as to the path of totality with respect to the position of his own observatory and came to the conclusion that the path would pass over Jackson or just to the north and he is glad to see his estimate confirmed by the Ephemeris for 1918. It will be found by examining the Ephemeris for 1918 that of those observatories in the United States, seventy two in all, having their positions indicated, Denver is the only one in the path of totality. The Ephemeris also shows Jackson in the path, which of course includes the James Observatory though, due to a failure to get the correct information to them in time, its position is not shown in the Ephemeris.

As our observatory is one of the two favored by the eclipse of 1918 June 8, I will give the coördinates and constants that are being used at the present time.

The order given in the Ephemeris will be followed here.

Place—Jackson, Miss.
Latitude $+32^\circ\ 19'\ 29''$.
Reduction to Geocentric Latitude $-10'\ 23''.548$.
Altitude meters: 109.
Log ρ: 9.9995865.
Longitude from Greenwich: $+6^h\ 0^m\ 43^s$.
Reduction from Greenwich to Local S.T.M.N. $+59^s.25$.
Latitude—Authority (Observations by Director).
Longitude " (Taken from Topographical Map U.S.G.S. Jackson Quadrangle Ed. Aug. 1908).

James Observatory.
Jackson, Miss.
February 28, 1916.

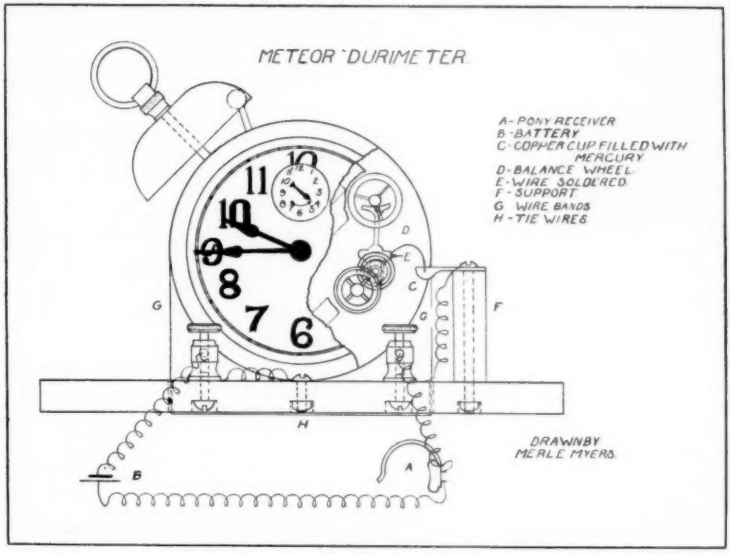
A DURIMETER FOR METEOR OBSERVATIONS.

LINCOLN LAPAZ.

Perhaps no more difficult a task can be required of an inexperienced observer than that of estimating the duration of an extremely transient appearance. Nowhere is the attempt to make such an estimation more perplexing than in meteoric work, especially since the mind is occupied in classifying the observed shooting stars as to color and magnitude or in determining the position of the apparent paths. Continued practice will, of course, relieve the arduousness of forming such estimations; nevertheless the amateur who desires to set down only such data as he sincerely believes to be correct will spend many puzzled moments over his recorded durations if he has nothing to guide him in his judgments. However, by introducing an alarm clock having a slightly modified escapement in an electric circuit containing a telephone receiver, it is possible to obtain a contrivance which will assist greatly in ascertaining the duration of visibility of meteors.

The clock is the only thing which must be changed, and it requires only slight alteration. After the back or face of the clock has first been removed, that part of the escapement which we are to work with may be recognized by its backward and forward motion and, in some cases, by its anchor like shape. It is designated by E in the accompanying drawing. The escapement is next brought to the side of the clock by tilting the timepiece as illustrated in the diagram and the wall of the clock cut away in front of it. A piece of No. 18 aluminium or copper wire, one inch in length, is pushed thru the aperture thus formed and soldered to the lower extremity of the anchor escapement in such a manner that a vertical motion will be given to the wire when the clockwork is in motion. When the clock is secured to the base by wire bands and screws, a tiny metal dipper, conveniently formed by denting one end of a two inch tin or copper strip, is mounted on a spool or similar support and fastened just below the outer end of the wire on the escapement, care being taken that the dipper does not actually touch any part of the clock. The end of the wire is now bent so that on its downward motion it will dip into the metal bowl. A copper wire is run from any portion of the clock to one of two binding posts fastened on the clock's base, and a second wire from the metal bowl to the other post. Finally mercury is poured into the dipper until the end of the wire, when at the lowest point of its path, just touches the surface of the liquid.

In use the clock is connected in a circuit with a dry battery and a telephone receiver as shown in the figure. The receiver should be of the pony or wireless type and must be provided with a headband; it is imperative that both hands be unencumbered. It is usually most convenient to leave the clock and battery indoors and run leads from the binding posts on the clock base to the place of observation where the receiver may be connected up.



If the receiver is put to the ear when the arrangement is wired up, a short buzz will be heard whenever the wire dips into the mercury and closes the circuit and another buzz when the wire leaves the surface of the mercury and breaks the circuit. Moreover the sound produced at magnetization has a quite different tone quality from the sound brought forth by demagnetization; and since the circuit is opened and closed four times a second, the interval between two dissimilar buzzes represents a quarter of a second and that between two consecutive like sounds a half of a second.

When the durimeter, as the appliance may be called, is first used, it will be found helpful to beat time with the fingers, in the unoccupied moments between meteors, until the rythm of the sounds produced in the receiver is thoroughly familiar. Moreover no opportunity for practicing the estimation of short durations should be lost, for the

conflicting reports received from the various witnesses of every great meteor testify to the need of observers prepared to gather trustworthy data from such rare phenomena.

It is true, of course, that the estimations still depend on the individual judgment, but with the constant standard of comparison and the rapid familiarity with brief durations which the apparatus affords it appears that more accurate estimates are certain.

High School, Wichita.

NOTE:—Mr. Lincoln LaPaz, of Wichita, Kansas, observed during 1915 over 1500 meteors, which he reported to the American Meteor Society, The last 600 of these were observed, using the instrument, described in the above article, to estimate their durations.

The details of these observations, which will appear in full in the 1914-1915 report, now about to be printed, were of such interest, that Mr. LaPaz, at my request, prepared a short account of his instrument for POAULAR ASTRONOMY.

Judging by the consistency of his results and their evident accuracy, all members are urged to have a similar one made for their use in future. The estimate of a meteor's duration is certainly the most uncertain of all the data our observers try to obtain, and the use of this simple device should make their estimates several times more accurate.

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REPORT ON MARS, No. 16.

WILLIAM H. PICKERING.

After a brief reference to a suggestion of Professor Russell, which will serve excellently as an Introduction, this Report will be devoted to a *resumé* of a few of the more important conclusions that we have reached as the result of a preliminary study of our observations during the past opposition.

PROFESSOR RUSSELL'S SUGGESTION.

In the Scientific American, March 4, p. 248, Professor Russell devotes a considerable portion of his space to a discussion of the appearance of the canals of Mars as described by various observers. As one of the four specialists, to whose work he particularly refers, the writer may say that he considers the article an eminently fair one, and that the explanation given for the fact that Dr. Lowell draws the canals very narrow, while some of the other observers draw the majority of them fairly wide is probably the true one. This explanation in brief is that it is merely a question of the personality of the observer.

Professor Russell then goes on to suggest that a series of disks should be prepared by a committee, and these disks observed by the four specialists through their telescopes, none of the observers having previously seen the disks near at hand. By means of a comparison of these drawings Professor Russell thinks it might be possible to determine the real nature of the markings on Mars. The writer, having used in the course of his observations various artificial disks, from the 8-foot round canvas screen erected in 1892 at an altitude of something over 16,000 feet in the Andes, and which was observed from a distance of eleven miles,* to the 2-inch glass plate placed in front of an oil lamp and condensing lens, and viewed from a distance of 1100 feet in Jamaica,† would like to make a few remarks on this suggestion.

Suppose that one of the disks prepared by the committee contained simply two lines, one very narrow and black, the other wider and fainter. It is quite possible that Dr. Lowell would represent these markings by two narrow dark lines exactly alike. It is possible that Professor Barnard, who is placed by Professor Russell at the other extreme of the observers, would represent them by two faint broad bands, while M. Jarry Desloges and the writer who in Professor Russell's opinion occupy an intermediate position, might, if the markings were faint enough, represent them both as lines, and if they were darker represent them both as bands.

Now what would the committee learn by a comparison of these results? In the first place they would learn that all four of the observers had represented the markings incorrectly. In the next place they would learn the peculiarity of each observer's method of representation, which would in this case be what we have here assumed. But would the committee learn anything about the canals on Mars? They would in part have explained the discrepancies in the observer's work, but I believe that is all. The same would be true of any other markings that the committee might have prepared.

Among the four or five larger and more conspicuous canals one can often see that there is a real difference in width, but we can also occasionally see that there is a real difference in blackness. Now what can we say about the fainter canals that are so difficult that they can only just be distinguished? Differences in width seem to be more frequent than differences in blackness, and are therefore generally assumed by the writer to be the real cause of the difference in appearance of the canals, but it is quite likely that in some cases both causes affect them. To come back to the final, and also the initial question,

* Annals of the Harvard College Observatory **32**, 117.

† Report on Mars, No. 11.

however, are the markings in reality canals at all, that is continuous narrow dark bands or lines, or is the appearance due simply to comparatively broad irregular areas of unequal density and size? Some evidence bearing on this question has been collected during the past opposition.

Appearance and Nature of the Canals.

About March 1 the character of some of the canals observed changed very markedly. Prior to that date most of them had existed as broad smoothly curved lines. While many of these remained visible, there now suddenly appeared a number of new canals, very narrow, and some of them strikingly straight and artificial looking. Their advent had been foreseen, and indeed referred to in our first report, as well as in several others. Thus in No. 8 we say "at the next opposition he [the writer] expects to draw them appreciably more narrow than in his present series of sketches." Although anticipated therefore, from earlier studies in Peru and elsewhere, it must be admitted that the suddeness of their appearance was a little startling. On February 28, ω 30°, M. D. May 18, seeing 10, no canals were detected on the disk save Deuteronilus, which appeared as a broad faint band some 300 miles in width. Two nights later March 1, ω 35°, M. D. May 19, seeing 8 and 7, the band had narrowed to about 0.3 its former width, and five other canals had appeared, all of them comparatively narrow and sharply defined. While the seeing was inferior to that on the night of the earlier observation, the canals were both sharper and distinctly narrower. What was particularly striking in some instances was their straightness. It gave them an artificial appearance that should be seen to be fully appreciated.

March 8, ω 332, the canal known in different sections as Protonilus and Deuteronilus stretched in a nearly due east and west direction, as an apparently absolutely straight line, from Coloe Palus to Siloe Fons, where it was joined nearly at right angles by the equally straight Gehon, slightly wider, and about three-fifths as long. Doubtless both canals were arcs of large radius, but they appeared absolutely straight to the eye. The width of Protonilus was measured as we shall see later, and found to be 94 miles. Its length was 1860 miles, or practically just 20 times its width. If the reader will draw on paper a rectangle five inches long by one-quarter of an inch in width, he will get somewhat the effect that this canal produces. Save the lake, Ismenius, located at its middle point, it did not seem possible that it contained any irregularities or sinuosities equal to its own breadth, nor perhaps even half as great.

On March 15 Mars was in conjunction with the Moon, the two bodies being at the same altitude, and some 5° apart. The Moon was 3.5 days short of being full, and the coarser lunar canals visible with a field or opera glass, and represented in Report No. 6, Figure 1, were conspicuous. Mars was examined with a power of 660, which brought it up within a distance of about 100,000 miles. The Moon was examined with a power of 4, which brought it within a distance of 60,000 miles. Objects of the same size upon their surfaces would therefore have about the same angular dimensions. It is recorded after alternately examining first one and then the other, that the two northern canals of Imbrium were just about as distinct as Thoth and Nilosyrtis. These are at present the two most conspicuous canals on Mars. They were seen on a much darker background, but had about the same apparent breadth as the two lunar canals. The Copernicus canals were not so strongly marked at this phase, and the components of the narrow double in the south-western quadrant were much narrower.

On March 21 it is recorded that Cerberus, another very distinct canal, was just about as clear and wide as those near Copernicus with the field glass. The Moon was then two days past the full. The writer takes this opportunity to state, that since Report No. 6 was written he has found that certain of the lunar canals there mentioned had been previously described and pictured by Dr. Cerulli, Flammarion II, 317. Dr. Cerulli's drawing is a little difficult to understand at first, as he does not show conspicuously the generally recognized features of the Moon, but by means of the description in the text, it is evident that several of his canals are identical with those shown in our report.

If instead of viewing the Moon with a field or opera glass, we use a small telescope magnifying only ten or twelve times, these lunar canals entirely disappear. Even with magnification eight they are hardly visible. In their place we find a more or less continuous line of broad shaded areas of irregular shape, and of varying and irregular density. If we could use double the magnification on Mars, let us say 1300, would the same result be obtained? The writer uses habitually a magnification of 660, half as high again as anybody else, but to increase the magnification further would be worse than useless, less instead of more would be seen.

But suppose the canals of Mars are of irregular outline and density, and not smooth and straight, what of it? So too our cultivated fields would appear to an observer on the Moon. The lunar canals act in a very different manner from the Martian ones, and are not subject to such singular, irregular, and unaccountable changes of appearance and position. The writer wishes distinctly to state that it is not so much the *straightness* of the canals of Mars, as the public generally

imagines, and as Professor Russell in his article suggests, as it is their *arbitrary and unaccountable changes*, that make us believe them artificial. Even if the canals were really perfectly straight and uniform, it would certainly be impossible for us to prove it.

Future Possible Magnification.

It may now perhaps be asked is there any hope then that we may ever use a power of 1300 on Mars. Probably not at any observatory with the telescopes now existing, because these telescopes have all been carefully tried, and 660 is the highest power that has proved practicable anywhere. It has however been shown here that it is perfectly possible to use to advantage a magnification of 60 per inch of aperture on Mars, whenever the seeing reaches 8, even for an 11-inch lens. It is not believed that the seeing in Jamaica is any better than in many other portions of the tropics, where uniform temperature and atmospheric pressure prevail. It seems perfectly possible theoretically to use a power of 60 per inch of aperture even for lenses 20 or 25 inches in diameter, provided the seeing reaches as high as 10. In summer seeing 10 is often reached in the tropics, and 12 is not uncommon. But in the August opposition Mars is at only two-thirds the distance that it was this year, so that with twice the aperture, used at that season of the year, it might even now be perfectly practicable to obtain the desired enlargement of its surface details. In order to compute the necessary aperture of our telescope we will start with the fact that the lunar canals are all resolved into irregular areas when the magnification is such as to bring the Moon within 30,000 miles of us. To bring Mars within this distance at an August opposition would require a magnification of 1,200. Using a magnification of 60 per inch of aperture would require a 20 inch glass. To be on the safe side we will say a 24-inch telescope.

August oppositions occur once every thirty-two years, and the next one will come in 1924. Twenty-four inch telescopes are not now uncommon, and as the advantages of the tropical atmosphere for astronomical research gradually become more and more widely known, it does not seem improbable that some day someone will locate a telescope of this size somewhere in the tropics, and we may then add materially to our present knowledge in all those directions where the best of seeing is a matter of vital consequence.

Width and Visibility of the Canals.

On March 14 and 15 the widths of several of the canals were measured by means of the Canal Scale, Report No. 7. A magnification of 660 was used in all cases, two measures of each canal being made

when possible. The corrected mean diameter of the planet expressed in arc was 11″.67, and the equivalent of 1″ was 361 miles, or 580 kilometers. The widest canals measured, Nilosyrtis and Thoth were found to have a breadth of 0″.30, and the narrowest Astusapes 0″.08. The mean average deviation was 0″.025, 9 miles, or 14.4 kilometers. The following widths were deduced, Protonilus 94 miles, Astusapes 30±6, Nilosyrtis 106±12, Thoth 106±12, Hyblaeus 42±6, Cerberus (mean) 94, Hades 94. An early measure of Cerberus was rejected as obviously erroneous. Its breadth varied appreciably in different places, being widest near Charontis. Astapus and Nasamon were both visible and rather difficult. They were the same width as Astusapes, 30 miles. The seeing varied from 9 to 11, so that this width may be considered about the narrowest visible when the planet is at the mean distance computed for these dates, 74,000,000 miles. When nearest us the minimum breadth would be reduced to about 15 miles.

The density of Nilosyrtis and Thoth was equal to the darkest band or stripe one could make on white paper with a number 4 pencil. It is thought that a month or two earlier in the season they were somewhat darker, but not so dark as the marking of a number 3 pencil. These measures may be compared with some made last November, see Report No. 13, and also with some made upon an artificial disk, Report No. 11, from which it was concluded that with moderately good seeing we should be able to detect a canal whose width was only 9 miles, if it were absolutely black.

Comparing these results again with observations made on the same night upon the two canals visible on the outer slopes of the lunar crater Aristillus, colongitude 39°.8, we find that with our 3-inch finder and magnification 240, the Aristillus canals are a trifle easier than Astusapes in the 11-inch. The breadth as measured with the finder was 0″.18 or 1100 feet. As measured with the 11-inch 0″.13, 800 feet, or 240 meters. This may indicate that with a still more powerful telescope than the 11-inch, the equivalent breadth of Astusapes might be also reduced, so as not to much exceed 20 miles. The density of the Aristillus canals was the same as those of Mars, that of a No. 4 pencil. Both Nilosyrtis and Thoth could be detected, although rather faintly in the finder. They were easier early in the season, and were not difficult at that time. With the 11-inch, Nilosyrtis and Thoth were both much easier than the Aristillus outer canals, while Astusapes was clearly more difficult.

Aryn, Elysium, the Snow Cap, and Vegetation.

While for many years changes on Mars have been recorded by all careful observers, it was not until the last two years that they have

been recognized as such a constant feature of the planet, and expected to occur anywhere at any time. Accordingly a universally accepted feature such as Aryn was formerly believed to be constantly present. The feeling was, that if it was not seen, it ought to have been, and so it was put down in the drawing whenever that part of the planet was visible, whether it was really seen or not. This, it is believed, accounts for its appearance on so many of the drawings made during the opposition of 1913-14, when it is now practically certain that it was not really visible at all.

In point of fact Aryn did not appear this year before March. On the first it was strongly suspected, but not surely seen. ω 3°.9, $\odot$ 61°.5 M. D. May 19, seeing 8, 7. March 3 it was recorded as pretty certainly there, but even on March 5, ω 0°.5, although certain, it was only very faintly marked, seeing 9. The appearance was little more than an indication of Aryn, for it consisted in a very shallow notch in the northern border of the bay of Sabaeus, with a scarcely noticeable lightening extending about one-third way towards the southern border. Indeed it would scarcely have been seen had not a special search been made for it. In 1914 it was not until April 14, three months after opposition, that Mars reached the same solar longitude $\odot$, that it had this year March 1.

The same remark is true of the pentagonal form of Elysium. Doubtless at certain seasons Elysium is pentagonal. Observers believed it was always so, and drew it accordingly, as a matter of habit. One cause of these errors is that observers have heretofore used too low powers,—possibly all that their aperture or their atmosphere would permit, but still too low. Mars is a very small object at the best, and the details of its surface minute. To see them well, and make no gross errors, we must have a reasonably large aperture, and we must have good seeing, and high magnification. Under these conditions, and a magnification of 600 or 700, the planet may be less distinct than with a power of 400, and certainly less pretty as a show object, but the observer familiar with its surface will see all its generally accepted details, such as the two above mentioned, more certainly, and can draw them more accurately, than when they are so small as to be on the very limit of distinct vision. If he is interested in hunting for fine canals, he may later use the low power, and insert what he sees on his previous sketch, but that is the only way that it should be used.

There is another interesting feature about Elysium as it has been seen at the past opposition. Its outline this year has been nearly circular, and the inner edges of the bounding canals, Cerberus, Styx, and Eunostos were all sharply defined, while their outer edges were less so. This is precisely the reverse of what is shown in Schiaparelli's

drawing in May 1888, when the outside is sharp, and the interior hazy. Flammarion I, 423. We have already seen in Report No. 13 that the advancing or eastern side of the north and south band was sharp while the other side was hazy. We have also seen by Report No. 12 that there was evidence that Elysium was subject to changes in size. It therefore appears possible that Elysium has been changing its size and growing smaller, while in 1888 it was growing larger. This suggestion is corroborated by measures of the drawings made hitherto this year, although the change found is so small that it can not be called conclusive. The mean inner meridianal diameter in January measured 859 miles, in February 806, and in March 778. Both inner and outer edges are now fairly sharp, so that it seems likely that the minimum size has been attained. It is now clearly smaller as well as rounder than it was early in the previous opposition of 1913-14.

The snow cap is now appreciably smaller than it was at the last opposition, at the same season of the year. Since as we have already seen it was much larger earlier in the season than at the former opposition, we can hardly doubt but that they have been having rather warmer weather on Mars this year. It will be of interest to note if this means a warmer summer than usual for our Earth.

It may be mentioned here that although we have watched the planet under very satisfactory circumstances throughout the whole of the spring of its northern hemisphere, yet not a trace of green has been detected in that region. The impression gathered has been that all the dark northern areas, and most of the canals observed have been simply marshes, or moistened soil. Possibly greens will appear in their autumn, or before. On the other hand the greens of the southern hemisphere, during their autumn, have been at times very striking. They have now all disappeared.

Shifting Features, and Period of Rotation.

In our last Report we referred to the large bay similar to Titanum which had recently appeared at the junction of Cimmerium and Laestrigon, and was shown on our drawings of February 7, 9, and 12. This bay is also shown in four drawings made by two of our Hawaiian correspondents, Mr. Midkiff and Dr. Romberg, on the evening of February 17. It appears again of large size on two drawings made February 10 and 14 which have recently been received from Mr. L. J. Wilson. On the latter drawing it is just about equal to Titanum, which is also shown not far from the limb. This drawing furthermore agrees in showing Titanum unusually far to the east of Charontis, that is in a very low longitude. In our last Report we gave it as the result of the

mean of the transits taken in December, January, and February as located in longitude 156°.4±0°.8. It was impossible to obtain its position accurately this past month, but on March 29 it was found to be but little over 159°, which indicates that it is now gradually shifting back to the position given to it on the map, in longitude 170°. The shift recorded is equivalent to 13°.6, a distance of 500 miles, or 800 kilometers.

The following determinations of the longitude of Margaritifer at the mouth of the Indus, have been secured by different observers:—

Schiaparelli	1877-79	17°.3	Lowell	1903	20°.7
Wislicenus	1890	23.9	Lau	1909	24.5
Pickering	1892	17.2	Jarry Desloges	1912	15.5
Lowell	1894	16.6	Pickering	1916	15.1

This last determination was made March 5, and rests on a single transit only, but serves to confirm the value of M. Jarry Desloges, whose observation indicates that the shift since 1909 has been about 350 miles, corresponding to an interval of 40 minutes in the time of transit. Since this point is near the equator it is readily seen, and its position can be determined with considerable accuracy. Observers do not usually give average deviations, but with careful work they should lie between 0°.5 and 2°.0, the corresponding errors being 2^m and 8^m in the time of transit.

The longitude of the northern tip of the Syrtis Major was determined on the nights of March 9, 11, and 14, results 283°.4, 282.3, 286°.9, mean 284°.2 ± 1°.8. Professor Barnard at my request made a determination March 15, obtaining 285°. This compares with Dr. Lowell's result obtained in 1903 of 284°.77 ± 0°.36, and that of M. Jarry Desloges in 1912 of 284°.0. These results agree very satisfactorily, and little more could be desired. If we go back twenty years however, after making the correction of —4°.8 made by Marth in the Ephemeris for 1896, we find that the longitude of the Syrtis according to Wislicenus in 1890 was then 291°.0. By the writer's results at Arequipa in 1892 it was 291°.3, according to Lowell in 1894 it was 287°.6 and finally according to Lau as late as 1909 it was 289°.4. The mean of the first four results is 284°.5 ± 0°.4, the mean of the last four 289°.8 ± 1°.3, difference 5°.3, 183 miles or 293 kilometers. Whether we include Lau's recent determination among the early ones or not makes little difference in the final result. Schiaparelli's determination in 1877, 285°.5 agrees well with the latest figures.

The Syrtis Major is the most conspicuous marking upon the planet. There is probably no point on the whole surface whose longitude is more readily determined than its northern tip. A difference of 5°.3 corresponds to a difference of 22 minutes in the time of transit of the central meridian. It is inconceivable that either set of observers should

have made such a mistake. That the difference is not due to an erroneous rate of rotation is shown by the fact that after an interval of 39 years, Schiaparelli's determination in 1877 of 285°.5 is but 1°.0 above the present mean value. Indeed the only possible explanation of these discrepancies seems to be that the point has shifted across the planet's surface.

A very valuable piece of evidence on this question may be obtained from Dr. Lowell's careful measures of Aryn in 1894 and 1916. In the Annals of the Lowell Observatory I, 53 he states that as the result of his observations in 1894 it appeared that Fastigium Aryn passed the central meridian by "the unmistakable amount of twenty minutes behind time." In consequence, on the next page, he offers the suggestion "that the received time of rotation of the planet is a trifle too small." Twenty minutes of time corresponds to a correction of 4°.8 of longitude, and in 1896 Marth added this 20^m to his ephemeris. In consequence of this change, when we wish to compare earlier determinations of longitude with later ones, we must, as above stated, reduce the earlier values by subtracting 4°.8. In Bulletin No. 60 Dr. Lowell says that his observations in 1916 show "the received ephemeris to be $11.73 \pm .12$ minutes behind time." This corresponds to a difference of longitude of 2°.9.

We must note that before it was the planet that was behind time, now it is the ephemeris. The correction in longitude must therefore be reversed. He accordingly in this bulletin computes a shorter period of rotation than the accepted value, instead of a longer one as he formerly suggested. According to Schiaparelli in 1879, the longitude of Aryn was 0°.9. Correcting this by 4°.8 gives us 356°.1. It appears therefore that in the 15 years between 1879 and 1894 Aryn increased its longitude by 3°.9 or 144 miles, and that during the 20 years between 1894 and 1914 its longitude diminished by 2°.9 or 107 miles. Lowell's latest results therefore very closely confirm Schiaparelli's original position. Indeed his final position differs but 37 miles from that found by the great Italian astronomer 35 years before. It is quite impossible that deviations of 20^m and 12^m should be due to accidental errors, for as Dr. Lowell very truly remarks in referring to the former, it is a quantity "raised well above the possibility of accident, since it is twenty-five times as great as the probable error of the observations."

In Flammarion's Mars I, 506 is given a list of the various determinations of the period of rotation of the planet published prior to 1887. From these Flammarion has selected the six which he considers the best, and takes their mean, arriving at the value $24^h\ 37^m\ 22^s.65$. The extreme values range between $22^s.603$ and $22^s.715$. These values are all based on a comparison of the early drawings of Huyghens and

Maraldi with later observations, the extreme range of dates extending from 1659 to 1881. This value of Flammarion's is the one hitherto used for computing the ephemeris, and is evidently very nearly correct. A shift in position of 1° at the end of 10 years will make a difference in the computed period of $0^s.0754$. An increase of $0^s.02$ in the adopted period to $24^h\ 37^m\ 22^s.67$ would bring Schiaparelli's and Lowell's latest observations into exact agreement, but it is clear that really reliable results will only be obtained by locating several points upon the surface of the planet, instead of using a single one as has been done hitherto.

Double Canals.

On several occasions during the past opposition the double effect has been fairly evident here, particularly during the month of March, when the canals were very narrow and often straight. Thus on March 3, $\omega 335°$, $\odot 62°.3$, seeing 9, magnification 660, Protonilus and Deuteronilus stretched as a strikingly straight narrow band across the disk, and the double effect was clearly seen at intervals. This does not however mean that the canal was clearly double. Such certainly was not the case, but the effect that other observers have described was clearly seen. The canal possessed a geometrical straightness, and a small but perceptible breadth. Once in five or ten seconds it appeared for perhaps half a second to be composed of two extremely sharp and extremely delicate parallel lines. The rest of the time it was a uniform band. One of these appearances was evidently an illusion, the question was which. For several reasons it was concluded that the brief double effect was the illusion, and the band the genuine appearance. Perhaps the most convincing argument (*a*) was derived from this same canal a month later April 7, when it again took on the double appearance. Its breadth was measured at this time by means of the Canal Scale, and was found to be only $0''.13$, or 58 miles. With an 11-inch telescope even two stars must be $0''.41$ apart in order to be separated. Two dark lines require a somewhat greater separation, $0''.58$. Next (*b*) the two lines were separated by a space greater than either of them, such as we are all familiar with in the drawings of double canals. Such defining power is theoretically entirely out of the question with any lens. (*c*) Very good seeing 8 to 10 is absolutely necessary in order to show the double effect, but with our very best seeing 11 to 12, the effect entirely vanishes.

In Lowell Observatory Bulletin No. 5 Dr. Lowell explains how he observed the double canals Euphrates, Hiddekel and Gehon with a 6-inch aperture, and found the separation to be $0''.27$, $0''.26$, and $0''.28$ respectively. From this we gather that the same phenomenon was

seen by both observers. In order to separate a real double canal with a 6-inch aperture the separation must be at least 1″.06. He also points out that apertures of 12 and 24 inches gave him approximately the same separation, that with the latter ranging from 0″.35 to 0″.19. In Bulletin No. 15 he states that "The doubles, like all delicate detail, appear not continuously, but by flashes of revelation according as the atmospheric waves permit of passage undisturbed." That is precisely the way they appeared to me. He further states that the breadth of the components is "about a third of the breadth of the light land between them." That is about my impression of them. From these facts it would appear that we both saw the same phenomenon, in spite of the fact that according to my measures the separation was less.

To explain the effect satisfactorily has hitherto proved a very difficult matter. My impression is that it is due to a slight shifting of the image due to the air currents. Usually this shifting is more or less continuous, irregular, and rapid, producing merely a slight blurring of the image. It is believed that occasionally this shifting momentarily becomes fairly regular like a vibration, owing to the action of the atmospheric waves, and that this lasts let us say for half a second or more at a time. We shall then get two images produced side by side. Such an appearance would be visible only for extremely narrow lines, such as are found on Mars, and under such circumstances both images might be distinct even if separated by but little over 0″.1.

The amount of the shift would doubtless be different on different days and at different places, so that uniformity of result is hardly to be expected. In this connection Dr. Lowell's remark "Under faulty visual conditions the doubles appear wider than they otherwise would, for some reason not easy to explain" is of interest. Clearly that is exactly the effect we should expect to find on this hypothesis. See (c) above. We may readily demonstrate the effect mechanically, by viewing an ink line in a vibrating mirror attached to a tuning fork, or more simply by tying a very small mirror to the stem of a T-square placed horizontally, and projecting a few inches over the edge of a table. On setting the mirror in vibration, the reflection of the line, or of a pencil held a few inches above the mirror, will be clearly seen to be doubled.

The writer is not aware that this explanation has been previously proposed, but it seems to him after having studied the appearance with some care, that it accounts satisfactorily for the facts observed with regard to this singular and obscure phenomenon. It certainly appears more plausible than that the canals are really double, and separated by an amount theoretically incapable of detection in the telescope. It is of course possible that wide doubles may exist on Mars like the one

on Aristillus. That is however a divergent pair, widely separated at one end. None such have been seen on Mars by the writer as yet, and he believes that if they exist they must be of very rare occurrence. It has been thought best on account of the length of this paper to defer the record of our observations in March and April until the next Report.

PLANET NOTES.

CLIFFORD C. CRUMP.

Occultations Visible at Washington.

Date 1916	Star's Name	Magnitude	IMMERSION. Washington M.T.	Angle f'm N.	EMERSION. Washington M.T.	Angle f'm N.	Duration
			h m	°	h m	°	h m
July 16	96 B Aquarii	6.5	18 29	339	18 40	318	0 11
23	17 Tauri	3.8	13 34	25	14 14	297	0 40
23	23 Tauri	4.3	13 56	90	14 54	230	0 58
23	η Tauri	3.0	14 30	76	15 36	243	1 5
23	28 Tauri	5.2	15 23	101	16 23	216	1 1
23	27 Tauri	3.7	15 29	126	16 8	192	0 39
Aug. 7	*b* Scorpii	4.7	7 7	115	8 27	268	1 20
10	127 G Sagittarii	6.4	4 48	61	5 44	292	0 56
10	172 B Sagittarii	5.8	5 46	44	6 38	305	0 52
10	189 B Sagittarii	6.1	8 38	48	9 49	282	1 10
10	208 B Sagittarii	6.1	12 30	69	13 35	246	1 5
12	29 Capricorni	5.5	10 47	61	12 2	235	1 15
13	ρ Aquarii	5.3	15 57	106	16 38	188	0 40
13	170 B Aquarii	6.0	17 44	84	18 34	218	0 50
15	22 Piscium	5.8	7 37	93	8 24	213	0 47
17	101 Piscium	6.2	8 46	75	9 38	235	0 51
24	Saturn	0.4	15 3	104	16 5	272	1 2

Planet Notes for July and August, 1916.

During the months of July and August the sun will move south and east. It will move from Gemini through Cancer, and into Leo. During this interval its declination will change from $+23°\ 7'\ 34''.5$, to $+8°\ 40'\ 35''.0$. Near the end of August the sun will be near the bright star Regulus. On July 29 there will be an annular eclipse of the sun. This eclipse will be visible in the southern part of Australia and Tasmania.

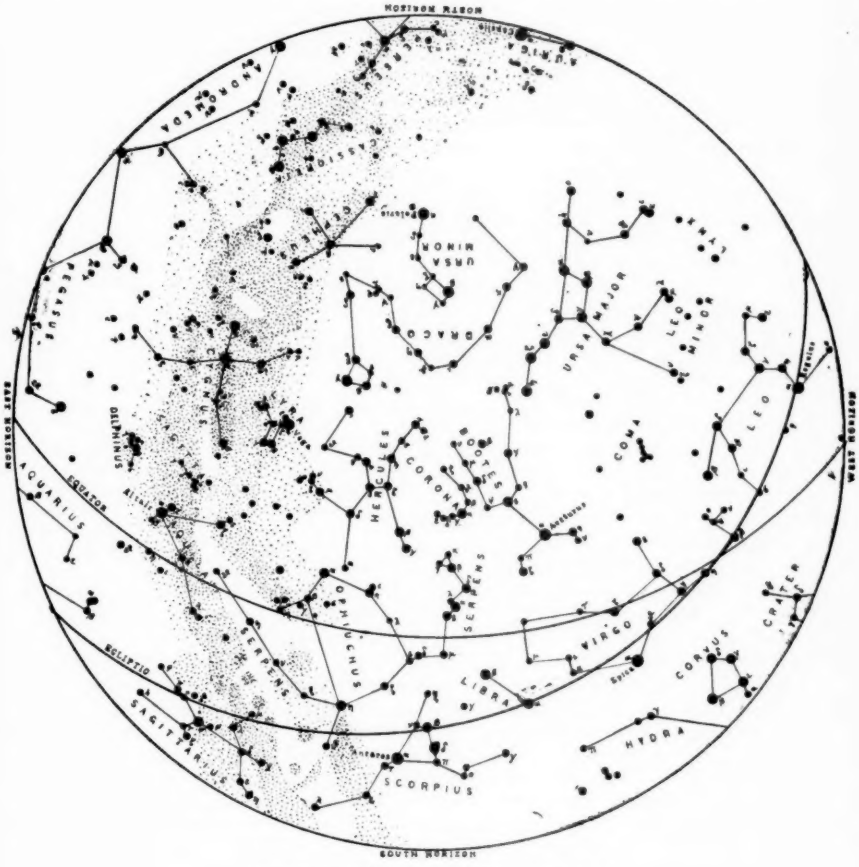
The phases of the moon for July and August are as follows:

			h	m		
First Quarter	July 8	at	5	55.0	A.M.	C.S.T.
Full Moon	14	"	10	40.0	P.M.	"
Last Quarter	21	"	5	33.0	P.M.	"
New Moon	29	"	8	15.4	P.M.	"
First Quarter	Aug. 6	"	3	5.6	A.M.	"
Full Moon	13	"	6	0.3	A.M.	"
Last Quarter	20	"	6	52.8	A.M.	"
New Moon	28	"	11	24.7	A.M.	"

The moon will be at apogee on July 28, and again on August 24. On July 14, and on August 12, it will be at perigee.

Mercury will be found at the beginning of July in the constellation of Taurus. It will have an eastward motion during the two months. It may be seen just before sunrise on July 1.

Venus will move in a retrograde direction in the constellation of Gemini until the first of August, it will then start to move eastward again. On July 3, it will



THE CONSTELLATIONS AT 9:00 P. M. JULY 1.

pass between the earth and the sun. During the month of August it will be the bright morning star.

Mars may be observed in the evening sky during the two months. It will move from the constellation of Leo into Virgo.

Jupiter will move eastward in the constellation of Aries until August 22. On this date it will begin to move in a retrograde motion. It may be observed after midnight during the month of August.

Saturn will be behind the sun on July 12. It will be occulted by the moon on August 24. On this date it will be of 0.4 magnitude.

Uranus will be best situated for observation on August 10, being at opposition on this date. It will be found in the constellation of Capricornus.

Neptune will not be visible because of its nearness to the sun.

The Frequency of Striking Conjunctions of Venus and Jupiter. The conjunction of Venus and Jupiter of February, 1916, raised the question of how often such conjunctions can occur. As Venus is never at a greater apparent distance from the sun than about 47°, a conjunction of Venus and Jupiter must occur within that limit, i. e., near conjunction of Jupiter and the Sun. But if a conjunction of the two take place exactly at that time, the retrograde motion of Venus is greater than that of Jupiter, and from this we see that two other conjunctions must take place near that time, one somewhat before and the other after. In this case we would have three conjunctions of Venus and Jupiter in a single synodic revolution of Jupiter. Otherwise there would be but one.

The synodic periods of Venus and Jupiter are very nearly commensurable with each other and with the year, the cycle comprising 155 years, 142 synodic revolutions of Jupiter and 107 of Venus. An investigation shows that if all the orbits were circular and in the same plane, a condition nearly satisfied by Venus, the Earth and Jupiter, three conjunctions of Jupiter and Venus would occur near any one conjunction of Jupiter and the Sun if the interval from this latter to the inferior conjunction of Venus were numerically less than 0.048 year, and that this must occur seven and may occur nine times in the cycle. With this criterion as a guide, a search of the ephemerides showed that there were actually eight such cases. Consequently in 155 years there are 134 conjunctions of Jupiter and the Sun producing one conjunction of Venus and Jupiter each, and eight producing three each, a total of 158.

But while there are 158 conjunctions in 155 years, there are other considerations affecting the interest of the phenomenon. First, approximately half of the conjunctions take place when the planets are morning stars, and are not noticed. Second, the inclinations of the orbit planes to each other and to the ecliptic cause the angular distance between the two bodies at conjunction to vary, sometimes being as much as eight degrees. For the conjunction to be really interesting they should pass within a degree of each other, which occurs about two thirds of the time. For it to be striking, or as close as that of this year, they must pass within half a degree, which occurs about one third of the time. Third, for the conjunction to be easily observable, the planets should be at least 15° from the Sun with ecliptic high, as it is from December to June, or 25° with it low, as it is from June to December. If we set 20° as an average limit we have our condition satisfied two thirds of the time. For the interested observer the distance could be decreased to 15° and the corresponding proportion would become three fourths. The interested observer would also avail himself of the morning conjunctions. And finally, the extreme proximity of the striking conjunctions lasts only a few hours. During this time the planets will be visible to only a part of the earth, being either below the horizon or in daylight for the remainder. The factor arising from this cause is hard to determine but will probably be about one half.

Forming the continued products of the various factors for each condition, we find that about one in two of the conjunctions will be interesting, while but one in eighteen or so will be as striking as that of this year. That is, about one every other year and one every fifteen to twenty years, respectively.

BERNHARD H. DAWSON.

Ann Arbor, 1916 April 29.

VARIABLE STARS.

The Variable Star *191033* **RY Sagittarii,** is now faint, and observations of its brightness will have much value. Its magnitude is ordinarily 6.5. It was found by Mr. Leon Campbell to be of the eleventh manitude on May 13. It is one of the three variables so far discovered which are bright for a large portion of the time, but occasionally become faint, and vary irregularly. The other two are 054319, SU Tauri, and 154428, R Coronae.

EDWARD C. PICKERING.

Harvard College Observatory,
Bulletin 610.
Cambridge, Mass., U. S. A.
May 17, 1916.

Maxima of Variable Stars of Short Period.

[Calculated by Bertha Booth and Bessie Burnham at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1916. July-August							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.4	36 13.7			11 20;	17 10				
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	8 14;	24 21;	10 3;	26 10				
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	1 8;	16 19;	1 7;	16 19				
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	13 12;	28 7;	12 2;	26 22				
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	7 1;	22 22;	7 19;	23 16				
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	3 21;	19 11;	4 1;	19 16				
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	2 23;	17 13;	8 9;	30 6				
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	12	28	13	29				
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	9 12;	26 16;	12 20;	29 23				
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	1 23;	24 6;	4 9;	26 15				
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0	2 17;	26 23;	6 14;	29 20				
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	1 20;	17 4;	1 11;	16 16				
SY Aurigae	05.5	+42 41	8.4— 9.5	10 03.3	2 20;	22 2;	11 9;	31 16				
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	2 2;	17 12;	1 22;	17 9				
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	4 11;	21 1;	1 2;	17 16				
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	6 13;	21 17;	5 19;	20 23				
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3	14 19		10 19					
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	8 0;	22 10;	5 20;	20 5				
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	2 19;	18 15;	3 11;	19 7				
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	3 6;	23 14;	2 17;	23 1				
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	4 14;	26 20;	18 3					
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	5 10;	21 7;	6 4;	22 2				
V Carinae	8 26.7	−59 47	7.4— 8.1	6 16.7	7 9;	20 18;	9 20;	29 22				

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1916. July-August							
	h m	° ′		d h	d h	d h	d h	d h				
T Velorum	8 34.4	−47 01	7.6— 8.5	4 15.3	8 18;	27 7;	5 14;	24 3				
V Velorum	9 19.2	−55 32	7.5— 8.2	4 08.9	8 12;	26 23;	3 17;	21 5				
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 0.0		25						
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	2 4;	22 13;	5 3;	25 11				
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	6 0;	19 5;	1 10;	21 5				
S Muscae	12 07.4	−69 36	6.4— 7.3	9 15.8	10 4;	29 11;	9 3;	28 10				
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	8 10;	24 9;	1 8;	17 7				
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	1 22;	22 2;	11 7;	31 12				
R Crucis	18.1	−61 04	6.8— 7.9	5 19.8	5 7;	22 18;	3 10;	20 21				
S Crucis	12 48.4	−57 53	6.5— 7.6	4 16.6	3 18;	22 12;	5 14;	24 8				
W Virginis	13 20.9	− 2 52	8.7—10.4	17 06.5	5 4;	22 11;	8 17;	26 0				
SS Hydrae	25.0	−23 08	7.4— 8.1	8 4.8	7 10;	23 19;	9 5;	25 14				
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	3 22;	17 23;	1 0;	22 1				
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	4 21;	21 7;	6 17;	23 3				
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	7 9;	18 9;	3 20;	25 20				
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	5 10;	20 12;	4 14;	19 16				
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	8 9;	23 5;	7 1;	21 20				
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	2 21;	23 5;	5 18;	19 8				
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	4 8;	23 7;	4 23;	23 22				
S Normae	16 10.6	−57 39	6.6— 7.6	9 18.1	1 18;	21 6;	9 18;	29 6				
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	3 6;	20 23;	7 16;	25 9				
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	6 21;	19 0;	6 4;	24 9				
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	5 2;	19 3;	9 4;	30 5				
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9	10 10;	27 12;	14 15;	31 18				
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	1 3;	23 21;	8 2;	23 7				
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	1 10;	18 18;	5 1;	22 9				
U Sagittarii	26.0	−19 12	6.5— 7.3	6 17.9	7 13;	21 1;	3 13;	23 18				
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	11 5;	31 21;	10 30;	21 14				
Y Lyrae	34.2	+43 52	11.3—12.3	0 12.1	5 14;	23 16;	10 19;	28 21				
RZ Lyrae	18 39.9	+32 42	9.9—11.2	0 12.3	6 14;	25 0;	12 10;	30 20				
RT Scuti	18 44.1	−10 30	9.1— 9.7	0 11.9	2 21;	20 18;	7 14;	31 9				
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	3 0;	21 4;	6 9;	25 13				
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	5 8;	19 9;	9 11;	30 12				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	5 5;	19 5;	2 5;	23 5				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	2 3;	18 2;	3 1;	19 0				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	3 0;	18 10;	2 19;	18 4				
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	4 3;	18 12;	9 0;	30 13				
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	1 21;	18 15;	4 9;	29 13				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	1 23;	20 22;	8 21;	27 20				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	9 5;	25 14;	11 0;	27 9				
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	3 18;	17 2;	3 20;	21 13				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	2 17;	22 21;	12 2;	25 13				
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	1 18;	21 22;	11 1;	31 5				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	3 10;	18 3;	1 20;	31 7				
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	2 5;	17 22;	2 15;	18 10				
SW Aquarii	10.2	− 0 20	9.9—10.8	0 11.0	5 12;	19 7;	8 23;	29 15				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	4 23;	19 14;	3 4;	17 18				
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	5 3;	22 10;	8 18;	26 1				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	5 3;	21 5;	6 8;	22 10				
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	9 0 ;	30 18;	10 15;	21 12				
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	1 10;	14 6;	2 12;	21 18				
V Lacertae	22 44.5	+55 48	8.5— 9.5	4 23.6	1 13;	26 12;	5 10;	20 9				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	6 11;	22 18;	8 2;	24 10				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	2 17;	21 14;	9 12;	28 9				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	1 1;	25 7;	6 11;	30 18				
V Cephei	23 51.7	+82 38	6.0—7.0	0 23.6	1 7;	21 6;	10 5;	30 4				

Minima of Variable Stars of Short Period.

[Calculated by Agnes E. Wells at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard 6h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1916 July-August							
	h m	° ′		d h	d h	d h	d h	d h				
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8					1 19			
RT Sculptor.	31.5	−26 13	9.6—10.5	0 12.3	4 8;	19 16;	4 0;	19 9				
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	1 2;	23 9;	7 6;	22 3				
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	5 6;	20 5;	4 4;	19 3				
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	7 21;	26 5;	7 10;	19 16				
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	2 17;	24 3;	7 10;	21 16				
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	6 9;	20 3;	2 20;	23 10				
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	6 3;	20 12;	3 20;	18 4				
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	9 11;	27 1;	4 19;	22 9				
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	8 21;	24 18;	1 17;	19 14				
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6		20 20		22 4				
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	~~3 10;~~	~~31 15;~~	~~2 2;~~	~~19 0~~				
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	4 13;	18 4;	7 13;	21 3				
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	3 7;	19 2;	3 22;	19 17				
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	2 4;	18 19;	4 10;	21 1				
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	8 0;	23 19;	8 14;	24 9				
RW Persei	13.3	+42 04	8.8—11.0	15 04.8	2 15;	29 0;	11 5;	24 10				
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	5 19;	24 16;	3 3;	22 0				
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	7 19;	20 5;	1 15;	26 11				
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	6 16;	20 0;	2 8;	22 8				
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	1 6;	17 15;	2 23;	19 9				
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	6 0;	24 2;	5 3;	23 4				
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	4 14;	21 22;	8 6;	25 14				
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	9 4;	30 0;	9 10;	19 19				
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	5 15;	21 16;	6 17;	22 17				
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	5 16;	22 21;	3 8;	20 13				
U Columbae	6 11.2	−33 03	9.2—10.0	2 19.2	4 10;	21 5;	1 10;	18 5				
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	1 3;	17 12;	2 22;	19 8				
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	5 14;	20 20;	5 2;	20 8				
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	1 12;	25 23;	7 3;	19 8				
RU Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	4 12;	18 20;	2 4;	23 16				
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	1 22;	20 2;	7 6;	16 8				
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	2 7;	20 21;	8 12;	17 19				
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	11 0;	31 7;	10 4;	20 3				
TX Gemin.	30.3	+17 8	10.0—11.9	2 19.2	4 15;	20 10;	6 5;	23 0				
RR Puppis	43.5	−41 08	9.4—10.7	6 10.3	1 22;	14 18;	9 11;	22 8				
V Puppis	7 55.4	−48 58	4.1— 4.8	1 10.9	5 0;	19 13;	3 2;	17 16				
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	9 3;	25 8;	2 11;	18 17				
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	6 1;	25 0;	3 12;	22 11				
RX Hydrae	9 00.8	− 7 52	9.1—10.5	2 6.8	2 1;	20 7;	7 13;	16 16				
S Antliae	27.9	−28 11	6.7— 7.3	0 07.8	5 3;	8 2;	6 12;	19 12				
S Velorum	29.4	−44 46	7.8— 9.3	5 22.4	4 16;	16 13;	3 8;	21 3				
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	2 12;	19 8;	5 5;	22 2				
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	3 3;	21 16;	9 5;	18 12				
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.2	7 11;	20 16;	2 21;	22 16				
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	8 19;	26 10;	4 5;	21 19				
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	1 14;	16 7;	7 7;	21 22				
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	4 5;	24 12;	7 3;	20 16				
RZ Centauri	12 55.6	−64 05	8.5— 8.9	1 21.0	4 8;	19 8;	3 8;	18 8				
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.2	10 12;	29 16;	8 7;	17 21				
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	2 23;	17 20;	1 17;	16 14				
δ Librae	14 55.6	− 8 07	4.8— 6.2	2 07.9	5 23;	19 22;	2 21;	16 20				

Minima of Variable Stars of Short Period—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1916 July-August
	h m	° ′		d h	d h d h d h d h
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	4 11; 18 6; 1 1; 21 18
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.4	8 12; 25 8; 2 18; 19 14
SS Librae	15 43.4	−15 14	9.3—11.5	0 18.4	2 20; 18 4; 2 11; 17 19
SW Ophiuchi	16 11.1	− 6 44	9.2—10.0	2 10.7	2 11; 24 11; 8 4; 22 20
SX Ophiuchi	12.6	− 6 25	10.5—11.2	2 01.5	7 18; 24 6; 1 12; 18 0
R Arae	31.1	−56 48	6.8— 7.9	4 10.2	7 7; 25 0; 2 20; 20 13
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	4 4; 24 22; 3 14; 14 16
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	1 10; 21 19; 4 10; 18 1
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	2 15; 19 9; 5 4; 21 22
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	5 17; 24 4; 5 11; 17 18
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	5 21; 20 8; 3 18; 18 4
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	6 12; 21 6; 5 0; 19 18
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	2 16; 19 1; 4 9; 20 18
TX Scorpii	48.6	−34 13	7.5— 8.2	0 22.6	5 3; 20 1; 4 7; 19 9
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	2 9; 17 21; 2 8; 17 20
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	6 22; 22 21; 7 20; 23 20
WX Sagittae	53.6	−17 24	9.2—10.8	2 03.1	1 11; 18 12; 4 13; 21 14
WY Sagittae	17 54.9	−23 1	9.5—10.6	4 16.0	4 22; 23 15; 1 23; 20 15
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	5 21; 26 13; 5 22; 26 14
RS Sagittarii	11.0	−34 08	5.9— 6.3	2 10.0	7 16; 22 4; 5 16; 20 4
V Serpentis	11.1	−15 34	9.5—11.1	3 10.9	1 22; 22 15; 5 11; 19 6
RZ Scuti	21.1	− 9 15	7.4— 8.3	15 03.2	1 17; 31 22; 16 2; 31 5
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	9 0; 25 13; 2 19; 19 8
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	4 11; 22 5; 9 0; 26 19
SX Sagittarii	39.7	−30 36	8.7— 9.8	2 01.8	2 4; 18 18; 4 9; 21 0
RR Draconis	40.8	+62 34	9.3—13	2 19.9	7 11; 24 11; 1 23; 18 22
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	6 7; 19 14; 1 21; 21 19
β Lyrae	46.4	+33 15	3.4— 4.1	12 21.8	4 13; 30 9; 13 6; 26 4
U Scuti	18 48.9	−12 44	9.1— 9.6	0 22.9	3 6; 22 8; 10 11; 19 23
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	3 8; 18 11; 2 15; 17 18
RV Lyrae	12.5	+32 15	11. —12.8	3 14.4	4 12; 18 22; 2 7; 16 17
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	9 1; 26 23; 4 22; 22 20
U Sagittae	14.4	+19 26	6.5— 9.0	3 09.1	3 13; 23 20; 6 8; 19 21
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	4 14; 19 7; 3 1; 17 18
TT Lyrae	24.3	+41 30	9.3—11.6	5 05.8	4 6; 14 18; 4 17; 21 11
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	5 2; 24 16; 6 17; 19 18
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	3 13; 21 13; 2 14; 20 14
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	3 19; 23 17; 5 23; 19 5
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	7 23; 26 6; 4 9; 22 16
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	7 18; 24 14; 2 1; 18 21
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	3 0; 23 8; 2 1; 22 8
UW Cygni	19.6	+42 55	10.5—10.8	3 13	1 7; 22 0; 4 20; 18 16
V Vulpec.	32.3	+26 15	8.2—9.8	37 19.0	14 14 21 9
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	3 3; 22 8; 10 14; 20 4
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	8 8; 26 18; 4 23; 23 9
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	6 12; 21 11; 5 11; 20 10
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	5 1; 22 14; 3 6; 20 19
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	9 23; 30 5; 9 6; 19 9
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	6 20; 21 14; 5 9; 20 3
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	9 9; 28 18; 7 10; 17 3
RY Aquarii	14.8	−11 14	8.8—10.4	1 23.2	1 14; 17 7; 2 1; 17 19
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3	20 10 20 17
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	2 17; 23 0; 2 4; 22 11
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	2 15; 18 4; 2 16; 17 6
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.6	3 9; 19 17; 5 1; 21 9
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.3	2 23; 19 13; 5 3; 21 17
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.4	3 0; 18 1; 2 3; 17 4
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	8 0; 24 12; 1 18; 18 5

COMET AND ASTEROID NOTES.

A New Comet.—On May 1 a telegram was received at the Harvard College Observatory from Copenhagen, announcing the discovery of a planet by Wolf at Heidelberg on April 27. This object has since been found to be a comet, and has been observed at those observatories having large telescopes. The following positions have been reported through the Harvard Circulars:

		α	δ			
		h m s	° ′ ″			
May	4.8565	12 36 55.6	+2 59 51	Van Biesbroeck	Yerkes	Observatory
	6.6559	12 36 10.3	3 7 46	Barnard	Yerkes	"
	6.6846	12 36 9.5	3 7 53	Burton	U. S. Naval	"
	10.6331	12 34 36.0	3 24 13	Barnard	Yerkes	"

An orbit of this comet has been computed by Mr. Van Biesbroeck at the Yerkes Observatory. The elements are given as follows:

Time of perihelion passage	(T) 1918, July 27, G.M.T.
Perihelion minus node	(ω) 162° 40′
Longitude of node	(Ω) 187 12
Inclination	(i) 40 9
Perihelion distance	(q) 1.516

The positions have been computed for a few dates. We give those which may still be of use to our readers.

	α	δ
	h ′ ″	° ′
June 1	12 29 16	+4 31
5	12 28 49	4 38

At the time of discovery the comet was within 26° of aphelion. It has a period of 7.81 years, an eccentricity of 0.6147, and semi-major axis, 3.936.

Elements of Taylor's Comet, (1915 *e*).—I am sending you my latest elements of Taylor's Comet based upon three normals from observations taken first week of December 1915, and first weeks of January and February 1916. On March 18, 1916 $13^h\ 40^m\ 5^s$ G.M.T., Professor Barnard of Yerkes Observatory observed the comet in the following position: $\alpha = 6^h\ 47^m\ 19^s.14$, $\delta = +\ 32°\ 16'\ 0''.40$. These elements give the following position for the same time: $\alpha = 6^h\ 47^m\ 9^s.72$, $\delta = +\ 32°\ 16'\ 9.''40$. Fairly good.

Geocentric position (normals) that the elements are based on.

	1915	° ′ ″	° ′ ″
t	= Dec. 7.7719	λ = 79 41 34.46	β = − 22 53 33.44
	1916		
t'	= Jan. 8.6177	λ' = 76 36 22.52	β' = − 12 10 37.14
t''	= Feb. 9.5742	λ'' = 82 33 10.06	β'' = + 0 27 40.59

	° ′ ″		
⊙	= 255 4 43.00	Log R	= 9.993434
⊙′	= 287 31 39.47	" R'	= 9.992715
⊙″	= 320 0 33.02	" R''	= 9.994218

	° ′ ″		° ′ ″
Ψ'	= 146 59 22.56	z'	= 19 48 36.21

ELEMENTS.

$$
\begin{aligned}
\text{Epoch} &= \text{Jan. } 8.6177 \text{ G.M.T., } 1916.\\
M &= 356^\circ\ 40'\ 17''.21\\
\omega &= 354\ \ 50\ \ 2\ .12\\
\pi &= 108\ \ 36\ \ 27\ .60\\
\Omega &= 113\ \ 46\ \ 25\ .48\\
i &= 15\ \ 40\ \ 5\ .42\\
\log a &= 0.547050\\
\log e &= 9.745211\\
\log q &= 0.194270\\
\mu &= 536''.3251
\end{aligned}
$$

Heliocentric positions from fifth and last hypothesis.

$$
\begin{aligned}
l &= 76\ 54\ 55.65 & b &= -\ 9\ 33\ 1.48\\
l' &= 95\ 19\ 29.15 & b' &= -\ 5\ 4\ 20.76\\
l'' &= 114\ 36\ 37.96 & b'' &= +\ 0\ 14\ 4.93
\end{aligned}
$$

$$
\begin{aligned}
\log r &= 0.219655 & u &= 322\ 5\ 42.47\\
\text{“}\ \ r &= 0.198869 & u' &= 340\ 53\ 23.37\\
\text{“}\ \ r &= 0.195130 & u'' &= 0\ 52\ 8.72
\end{aligned}
$$

CONSTANTS.

$$
\begin{aligned}
x &= r\,(9.986314)\ \sin\,(204\ 35\ 3.65 + u)\\
y &= r\,(9.981829)\ \sin\,(118\ 54\ 21.24 + u)\\
z &= r\,(9.575159)\ \sin\,(\ 75\ 38\ 8.01 + u)
\end{aligned}
$$

F. E. SEAGRAVE.

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, Apr.-May, 1916.

The marked increase in the number of observations contributed this month is most gratifying, and we submit this month the best report of the year thus far.

Mr. Bancroft leads with a good list of 228 observations, many of them early morning observations, which have a special value. Messrs. Eaton and McAteer deserve mention for lists of great merit contributed to this report.

It is a pleasure to welcome as a new member of the Association Mr. Paul. S. Yendell, of 19 Winter St., Dorchester, Mass., an eminent authority on variables, the discoverer of many of them, and one of the pioneer variable star observers in this country. Mr. Yendell honors the Association in applying for membership, and kindly offers to assist any of our members who desire special information respecting variable stars. Observations contributed by Mr. Yendell to the reports will be indicated by the Greek capital letter upsilon "Υ". Messrs. Miner, "Mr" and Whitehorn, "Wh" join the ranks of active observers this month, and contribute to this report.

We regret to announce that Mr. Spinney has been obliged to discontinue the observation of variables for the time being. Mr. Spinney has rendered the Association valuable and faithful service, and we shall miss his participation in the reports.

VARIABLE STAR OBSERVATIONS Apr.-May, 1916.

001755
T Cassiop.

J.D. 242	Est.	Obs.
0956.6	8.8	Bu
73.6	9.3	Pi

004958
W Cassiop.

J.D. 242	Est.	Obs.
0956.6	9.4	Bu
71.6	9.0	Ba
73.6	9.0	Bu

012350
RZ Persei

J.D. 242	Est.	Obs.
0956.6	9.5	Bu
73.6	9.4	Bu

014958
X Cassiop.

J.D. 242	Est.	Obs.
0956.6	9.6	Bu
59.6	10.1	Y
73.6	9.5	Bu
74.6	10.0	Y
88.5	9.6	Y

015354
U Persei

J.D. 242	Est.	Obs.
0956.6	9.2	Bu
63.6	8.9	V
73.6	9.4	Bu

021024
R Arietis

J.D. 242	Est.	Obs.
0949.6	8.2	R

021281
Z Cephei

J.D. 242	Est.	Obs.
0963.6	<11.5	V

021558
S Persei

J.D. 242	Est.	Obs.
0956.6	9.3	Bu
61.7	9.6	R
69.6	9.1	Ba

022150
RR Persei

J.D. 242	Est.	Obs.
0974.5	<12.4	Y

023133
R Triang.

J.D. 242	Est.	Obs.
0949.6	7.0	R

024356
W Persei

J.D. 242	Est.	Obs.
0956.5	10.0	O
56.6	10.2	Bu
61.6	10.4	R
69.6	9.3	Ba
74.5	9.8	Ba
83.6	9.6	Ba

032043
Y Persei

J.D. 242	Est.	Obs.
0956.6	9.5	Bu
61.7	8.5	R
69.6	8.5	Ba
74.5	8.6	Ba

032335
R Persei

J.D. 242	Est.	Obs.
0969.6	9.2	Ba
74.5	8.9	Ba

033362
U Camelop.

J.D. 242	Est.	Obs.
0956.6	7.5	Bu
69.6	7.2	Ba
74.5	7.4	Ba
83.6	8.2	Pi
84.6	7.2	Ba

042215
W Tauri

J.D. 242	Est.	Obs.
0972.6	11.0	M

043065
T Camelop.

J.D. 242	Est.	Obs.
0956.6	8.4	Bu
71.6	8.5	Ba
73.6	8.2	Bu
76.6	8.0	M
82.7	8.2	M
83.6	8.6	Pi
84.6	8.2	Ba

043274
X Camelop.

J.D. 242	Est.	Obs.
0949.7	8.5	R
56.5	8.2	O
56.6	8.3	Bu
59.5	8.2	O
59.6	8.5	Cr
60.6	8.8	Cr
63.6	8.9	V
64.5	8.7	O
64.6	8.5	Ba
64.6	8.4	Cr
69.6	9.0	Ba
71.6	9.0	Ba
72.6	9.3	Pi
73.5	9.5	O
73.6	9.1	Bu
73.6	9.6	Y
74.6	9.6	O
74.6	9.3	Ba
79.7	9.8	M
81.6	10.2	Cr
82.7	10.2	M
83.6	10.8	Pi
83.6	10.3	Ba
84.5	10.4	O
88.5	11.3	Y

050953
R Aurigae

J.D. 242	Est.	Obs.
0949.7	9.0	R
56.6	8.3	Bu
58.6	8.7	M
69.6	8.5	Ba
74.5	8.5	Ba
83.6	8.8	Pi
83.6	8.5	Ba

052034
S Aurigae

J.D. 242	Est.	Obs.
0956.6	8.8	Bu
69.6	8.8	Ba
74.6	8.8	Ba
83.6	8.9	Ba

052036
W Aurigae

J.D. 242	Est.	Obs.
0969.6	10.4	Ba
74.6	9.8	Ba
74.6	10.3	Y
83.6	9.6	Ba

053068
S Camelop.

J.D. 242	Est.	Obs.
0973.6	9.7	Y

053531
U Aurigae

J.D. 242	Est.	Obs.
0974.6	<12.7	Y

054319
SU Tauri

J.D. 242	Est.	Obs.
0956.6	9.5	E
56.5	9.4	O
56.6	9.3	Bu
59.5	9.5	O
62.6	9.6	E
63.6	9.5	V
69.6	9.1	Ba
73.5	9.4	O
74. 6	9.4	Ba
74.6	9.7	Y
83.6	9.5	Ba

054615
RU Tauri

J.D. 242	Est.	Obs.
0974.6	<12.5	Y

054615
Z Tauri

J.D. 242	Est.	Obs.
0974.6	<12.0	Y

054920
U Orionis

J.D. 242	Est.	Obs.
0956.5	9.7	O
56.6	10.0	Bu
71.6	8.9	Ba
72.6	9.6	M
73.5	9.3	O

054974
V Camelop.

J.D. 242	Est.	Obs.
0958.6	<10.9	M
64.5	12.0	Ba
72.6	<10.9	M
73.6	12.3	Y
74.7	<10.9	M
79.7	<10.9	M
82.7	<10.9	M
82.6	12.8	B
83.6	<11.6	Pi
83.6	<12.8	Ba
88.5	12.4	Y

055353
Z Aurigae

J.D. 242	Est.	Obs.
0956.6	9.8	Bu
69.6	10.5	Ba
72.6	10.7	M
74.6	10.5	Y
83.6	10.7	Pi
83.6	10.6	Ba

060450
X Aurigae

J.D. 242	Est.	Obs.
0955.6	10.4	E
56.6	10.9	Bu
69.6	10.0	Ba
73.6	10.5	Bu
73.6	9.8	Y
74.6	10.1	Ba
83.6	9.2	Pi
83.6	9.0	Ba

060547
SS Aurigae

J.D. 242	Est.	Obs.
0955.6	<12.6	E
56.6	<10.8	O
62.6	<11.6	E
63.6	11.1	V
64.6	10.7	Ba
66.6	12.0	Ba
69.6	<12.5	Ba
71.6	<12.0	Ba
72.6	<10.8	M
73.5	<10.8	O
73.6	<13.3	Y
74.6	<12.0	Ba
82.5	<13.0	B
83.6	<13.3	Ba
84.4	<13.3	Ba
88.6	<13.3	Ba

061647
V Aurigae

J.D. 242	Est.	Obs.
0956.6	<11.1	Bu
73.6	<11.1	Bu
84.6	11.6	Ba

061702
V Monoc.

J.D. 242	Est.	Obs.
0956.6	9.8	Bu

063159
U Lyncis

J.D. 242	Est.	Obs.
0956.6	<10.7	Bu
69.6	13.6	Ba
73.6	<10.7	Bu
73.6	<13.1	Y
83.6	13.6	Ba

063558
S Lyncis

J.D. 242	Est.	Obs.
0955.6	12.7	E
73.6	<12.6	Y

064030
X Gemin.

J.D. 242	Est.	Obs.
0955.7	<11.7	E
69.6	12.0	Ba
74.6	11.8	Ba
83.6	11.3	Ba

064932
Nova. Gemin. 2

J.D. 242	Est.	Obs.
0955.7	13.2	E

065111
Y Monoc.

J.D. 242	Est.	Obs.
0955.7	12.3	E

065208
X Monoc.

J.D. 242	Est.	Obs.
0956.6	7.4	Bu
61.6	7.2	R
69.6	8.3	Ba
73.6	7.6	Bu
75.7	7.6	R
83.6	8.7	Ba

065355
R Lyncis

J.D. 242	Est.	Obs.
0949.7	7.8	R
56.6	8.3	Bu
73.6	8.8	Y
75.7	9.6	R

070122a
R Gemin.

J.D. 242	Est.	Obs.
0956.6	<11.1	Bu
8.4	<12.5	Nt

070122
TW Gemin.

J.D. 242	Est.	Obs.
0956.6	8.2	Bu
75.7	8.5	R
84	8.3	Nt

070122b
Z Gemin.

J.D. 242	Est.	Obs.
0956.6	<11.1	Bu

070310
R Can. Min.

J.D. 242	Est.	Obs.
0956.6	9.5	Bu
59.5	9.4	O
69.6	8.5	Ba
73.5	8.9	O
83.6	8.3	Ba

071713
V Gemin.

J.D. 242	Est.	Obs.
0969.6	10.9	Ba
71.6	10.5	Ba
74.6	10.8	Y
83.6	10.1	Ba

VARIABLE STAR OBSERVATIONS Apr.-May, 1916—Continued.

072708
S Can. Min.

J.D. 242	Est.	Obs.
0956.6	10.4	Bu
58.6	10.6	M
60	10.8	Mu
62.7	8.3	R
69.6	11.4	Ba
83.6	11.6	Ba

073508
U Can. Min.

J.D. 242	Est.	Obs.
0952.6	9.6	R
56.6	9.2	Bu
58.6	9.6	M
59.5	9.5	O
69.6	9.5	Ba
73.5	9.7	O
74.6	9.7	Y
83.6	9.7	Ba
84.6	9.8	O

073723
S Gemin.

J.D. 242	Est.	Obs.
0963.6	<10.8	V
82.6	11.7	B

074922
U Gemin.

J.D. 242	Est.	Obs.
0955.6	<12.4	E
56.6	<11.4	O
62.6	<12.4	E
63.6	<11.4	V
69.6	<13.3	Ba
72.6	<11.4	M
73.5	<10.9	O
74.6	<12.6	Y
74.6	<10.9	O
74.7	<10.9	M
79.7	<11.4	M
82.6	<13.5	B
83.6	<10.9	O
83.6	<13.7	Ba
84	<12.4	Nt
84.6	<10.9	O
84.6	<13.3	Ba
85.6	<10.0	O
88.6	<13.3	Y

081112
R Cancri

J.D. 242	Est.	Obs.
0952.7	9.2	R
58.6	8.3	Bu
69.6	7.7	Ba
73.6	8.4	O
73.6	8.1	Bu
74.6	8.5	Pi
75.7	8.6	R
83.6	8.4	O
83.6	7.4	Ba

081617
V Cancri

J.D. 242	Est.	Obs.
0952.7	8.8	R
58.6	9.0	Bu
69.6	9.2	Ba
73.6	9.6	O
73.6	9.4	Bu
83.6	9.9	Ba
84.6	10.0	O

082405
RT Hydrae

J.D. 242	Est.	Obs.
0958.6	8.2	Bu
84.6	7.5	Ba

083019
U Cancri

J.D. 242	Est.	Obs.
0955.6	<12.9	E
84.6	<12.5	Ba

084803
S Hydrae

J.D. 242	Est.	Obs.
0958.6	<10.2	Bu

085008
T Hydrae

J.D. 242	Est.	Obs.
0956.5	<10.0	O
58.6	<9.9	Bu

085120
T Cancri

J.D. 242	Est.	Obs.
0984.6	9.4	Ba

090151
V Urs. Maj.

J.D. 242	Est.	Obs.
0949.6	10.4	R
52.6	10.6	R
53.7	10.2	R
56	9.9	Mu
60	9.8	Mu
61.7	10.6	R
62.7	10.4	R
63.6	9.5	V
69.6	10.0	Ba
75.7	10.3	R
76.7	10.5	R
76	9.8	Mu
81	9.7	Mu
83.6	10.1	Ba

090425
W Cancri

J.D. 242	Est.	Obs.
0969.6	12.2	Ba
83.6	11.3	Ba

093014
X Hydrae

J.D. 242	Est.	Obs.
0952.7	9.0	R
58.6	9.3	Bu
84.6	10.2	Ba

093178
Y Draconis

J.D. 242	Est.	Obs.
0974.6	10.6	Y

093934
R Leo. Min.

J.D. 242	Est.	Obs.
0953.6	8.4	R
58.6	9.0	Bu
69.6	8.4	Ba
74.6	9.0	Pi
83.6	8:9	Ba

094211
R Leonis

J.D. 242	Est.	Obs.
0953.6	9.3	R
55.7	9.0	E
56	9.4	Mu
58.6	9.6	Bu
59.5	9.9	O
60	9.4	Mu
63	9.4	Mu
69.7	8.9	Ba
73.6	9.7	Bu
73.6	9.6	O
74.6	9.8	M
74.6	9.8	Pi
74	9.3	Mu
76	9.4	Mu
81	9.4	Mu
83.6	9.7	O
83.6	8.9	Ba

094622
Y Hydrae

J.D. 242	Est.	Obs.
0953.7	7.0	R
58.6	6.8	Bu
75.7	7.5	R
84.6	6.5	Ba

095421
V Leonis

J.D. 242	Est.	Obs.
0982.6	<13.5	B
83.6	<13.6	Ba

103212
U Hydrae

J.D. 242	Est.	Obs.
0953.7	5.3	R
75.7	4.8	R

103769
R Urs. Maj.

J.D. 242	Est.	Obs.
0958.6	11.4	M
60	11.1	Mu
69.7	11.3	Ba
73.5	11.7	Pi
74.6	11.5	Ba
83.6	12.0	Ba

104620
V Hydrae

J.D. 242	Est.	Obs.
0953.7	7.7	R
58.6	6.6	Bu
75.7	7.7	R
84.6	6.0	Ba

104814
W Leonis

J.D. 242	Est.	Obs.
0982.6	<13.4	B

115919
R Comae

J.D. 242	Est.	Obs.
0964.5	<10.0	O
69.6	<12.0	Ba
72.5	<11.0	Pi
74.6	<13.0	Ba

120012
SU Virginis

J.D. 242	Est.	Obs.
0958.7	10.4	Bu
64.6	9.0	O
64.6	9.9	Ba
71.6	9.3	Ba
79.7	9.0	M
83.6	9.0	Ba

120905
T Virginis

J.D. 242	Est.	Obs.
0958.7	10.8	Bu
63.6	10.3	V
64.6	10.3	Ba
79.7	11.4	M
83.6	10.8	Ba
88.6	11.4	Y

121418
R Corvi

J.D. 242	Est.	Obs.
0953.7	7.5	R
58.7	7.3	Bu
59.0	7.2	Ho
64.6	7.0	Ba
71.6	7.1	Ba
75.7	8.0	R
79.7	7.5	M
83.6	8.0	Ma
83.6	7.4	Ba
84	7.5	Nt

122001
SS Virginis

J.D. 242	Est.	Obs.
0958.7	8.3	Bu
64.6	8.6	O
64.6	7.8	Ba
71.6	7.5	Ba
79.7	9.4	M
83.6	8.0	Ba

122303
V Virginis

J.D. 242	Est.	Obs.
0959.0	9.0	Ho

122532
T Can. Ven.

J.D. 242	Est.	Obs.
0956.6	9.7	O
58.7	10.0	Bu
64.5	9.7	O
64.6	9.5	Ba
71.6	9.2	Ba
74.6	9.5	Pi
74.6	9.6	M
82.7	9.8	M
84.6	9.4	Ba

122802
Y Virginis

J.D. 242	Est.	Obs.
0959.0	12.0	Ho
64.6	<12.0	Ba
74.6	<12.2	Ba
82.6	13.0	B

123160
T Urs. Maj.

J.D. 242	Est.	Obs.
0955.6	11.5	E
58.7	11.2	Bu
64.6	10.0	Ba
69.7	9.4	Ba
72.6	8.9	M
73.5	9.4	Pi
74.6	8.8	M
74.6	9.0	Ba
74	9.3	Mu
76	9.1	Mu
80.8	8.6	E
83.6	8.4	Ba
85.6	8.6	O
93.6	8.1	O

123307
R Virginis

J.D. 242	Est.	Obs.
0958.7	10.9	Bu
64.6	10.6	Ba
74.6	9.9	Ba
79.7	9.4	M
80.8	9.2	E
83.6	9.0	Ba
85.6	9.0	O
90.7	8.6	O
90.7	8.5	Pi
90.7	8.1	Ba
90.7	8.0	C
93.6	8.2	O

123459
RS Urs. Maj.

J.D. 242	Est.	Obs.
0974	10.5	Mu
76	10.1	Mu
83.6	<13.3	Ba

123961
S Urs. Maj.

J.D. 242	Est.	Obs.
0955.6	10.1	E
56.5	10.0	O
58.6	10.0	M
58.7	10.0	Bu
64.6	10.4	Ba
69.6	10.5	Ba
72.6	10.7	M
73.5	10.6	Pi
74.6	11.0	Ba
74	10.6	Mu
76	10.4	Mu
80.8	11.0	E
83.6	11.2	Ba

VARIABLE STAR OBSERVATIONS Apr.-May, 1916—Continued.

124204
RU Virginis

J.D. 242	Est.	Obs.
0974.6	<12.8	Ba
82.6	<13.3	B

124606
U Virginis

J.D. 242	Est.	Obs.
0958.7	8.3	Bu
64.6	8.8	O
64.6	8.6	Ba
73.6	8.7	O
74.6	8.4	Ba
79.7	8.5	M
83.6	8.6	Ba
83.8	8.7	Pi
84.6	8.7	O
93.6	8.7	O

132002
W Virginis

J.D. 242	Est.	Obs.
0979.7	10.1	M

132202
V Virginis

J.D. 242	Est.	Obs.
0974.6	8.8	Ba
79.7	9.8	M
84.6	8.8	Ba

132422
R Hydrae

J.D. 242	Est.	Obs.
0981.0	7.8	Mu

132706
S Virginis

J.D. 242	Est.	Obs.
0964.6	9.9	Ba
74.6	10.9	Ba
79.7	10.8	M
83.6	10.7	Y
84.6	11.2	Ba

134440
R Can. Ven.

J.D. 242	Est.	Obs.
0958.6	8.9	M
58.7	9.0	Bu
59.5	9.1	O
64.5	9.6	O
64.6	9.1	Ba
71.6	9.1	Ba
72.6	9.5	M
73.6	10.0	O
80.8	9.8	E
82.7	9.8	M
83.6	10.1	Ba

135908
RR Virginis

J.D. 242	Est.	Obs.
0979.7	<11.8	M

141567
U Urs. Min.

J.D. 242	Est.	Obs.
0964.6	10.4	Ba
71.6	10.4	Ba
73.6	10.8	Pi
83.6	10.5	Ba

141954
S Bootis

J.D. 242	Est.	Obs.
0964.6	11.6	Ba
71.6	11.2	Ba
83.6	10.6	Ba

142205
RS Virginis

J.D. 242	Est.	Obs.
0974.6	11.6	Ba

142539
V Bootis

J.D. 242	Est.	Obs.
0958.7	9.9	Bu
59.5	9.8	O
64.6	9.3	Ba
71.6	9.0	Ba
72.6	9.1	Pi
73.6	9.7	O
74.6	9.2	M
83.6	9.0	Ba
84.6	9.4	O
93.6	9.3	O

142584
R Camelop.

J.D. 242	Est.	Obs.
0956.5	9.1	O
59.5	9.0	O
64.5	9.0	O
73.5	8.4	O
76.7	9.0	R
83.6	8.4	O
84.6	8.3	Ba
93.6	8.1	O

143227
R Bootis

J.D. 242	Est.	Obs.
0974.6	11.1	O
74.6	<11.2	M
74.6	11.1	Ba
83.6	9.8	Ba
84.6	10.1	O
93.6	9.2	O

144918
U Bootis

J.D. 242	Est.	Obs.
0963.6	10.7	V
74.7	10.7	M
74.6	10.8	Ba
84.6	11.1	Ba

150018
RT Librae

J.D. 242	Est.	Obs.
0958.0	<12.6	Ho
83.7	<13.0	Ba

150519
T Librae

J.D. 242	Est.	Obs.
0958.0	12.5	Ho
83.7	<13.0	Ba

150605
Y Librae

J.D. 242	Est.	Obs.
0958.0	11.2	Ho
83.7	11.9	Ba

151520
S Librae

J.D. 242	Est.	Obs.
0958.0	11.0	Ho
62.8	11.0	E

151614
S Serpentis

J.D. 242	Est.	Obs.
0984.6	12.2	Ba

151731
S Cor. Bor.

J.D. 242	Est.	Obs.
0964.6	9.5	Ba
71.6	9.1	Ba
73.6	9.8	O
74.6	9.9	O
74.7	9.6	M
83.7	10.0	Ba
84.6	10.0	O
93.6	10.0	O

152714
RU Librae

J.D. 242	Est.	Obs.
0958.0	10.7	Ho
83.7	8.7	Ba

153378
S Urs. Min.

J.D. 242	Est.	Obs.
0960	9.0	Mu
63	8.9	Mu
64.6	8.7	Ba
71.6	8.5	Ba
72.7	9.2	M
73.6	8.9	Pi
73.6	9.8	Bu
74	8.7	Mu
76	8.6	Mu
81	8.5	Mu
83.7	8.4	Ba

154428
R Cor. Bor.

J.D. 242	Est.	Obs.
0956.6	6.1	Nt
56.6	6.0	O
56.9	6.0	E
58.7	6.0	Bu
59.6	6.0	Nt
61.6	5.9	Nt
62.8	6.1	E
63.6	5.8	Ba
64.6	5.9	Nt
64.6	5.8	Ba
66.6	5.8	Ba
71.6	5.5	Ba
73.6	6.0	O
74.5	5.9	Nt
74.6	6.0	O
74.7	6.0	M
74.6	5.7	Ba
74	6.2	Mu
75	6.1	Mu
75.7	6.2	R
76.7	5.9	R

R Cor. Bor.

J.D. 242	Est.	Obs.
76	6.0	Mu
77.6	6.0	E
77	6.1	Mu
78	6.0	Mu
79.7	6.0	M
79	6.1	Mu
80.7	6.0	E
81	5.7	Mu
82	5.9	Mu
82.6	5.9	Ma
83	6.0	Mu
83.6	6.4	Ma
83.7	6.0	Ba
84.6	6.0	O
84.6	5.9	Nt
84	6.0	Mu
84.6	6.0	Ba
90.7	6.0	Mr
90.7	6.0	Wh
93.6	6.0	O

154536
X Cor. Bor.

J.D. 242	Est.	Obs.
0974.6	11.6	Ba
83.7	11.7	Ba

154539
V Cor. Bor.

J.D. 242	Est.	Obs.
0971.6	8.3	Ba
79.7	9.7	M
83.7	8.6	Ba

154615
R Serpentis

J.D. 242	Est.	Obs.
0962.8	7.5	E
64.6	7.5	Ba
71.6	7.5	Ba
74.6	7.4	O
80.9	7.6	E
83.7	7.3	Ba
84.6	7.4	O
93.6	8.0	O

155229
Z Cor. Bor.

J.D. 242	Est.	Obs.
0984.6	12.5	Ba

155847
X Herculis

J.D. 242	Est.	Obs.
0959	6.9	Nt
61	6.9	Nt
64	6.9	Nt
74	6.9	Nt
84	6.9	Nt

160118
R Herculis

J.D. 242	Est.	Obs.
0971.6	9.8	Ba
83.7	10.7	Pi
83.7	10.7	Ba

160210
U Serpentis

J.D. 242	Est.	Obs.
0962.8	9.3	E
64.6	9.5	Ba
71.6	10.0	Ba
83.7	10.3	Ba

160625
RU Herculis

J.D. 242	Est.	Obs.
0964.6	11.1	Ba
83.7	11.0	Pi
83.7	10.8	Ba

161138
W Cor. Bor.

J.D. 242	Est.	Obs.
0962.8	12.5	E
74.6	<11.2	O
83.7	13.0	Ba

162112
V Ophiuchi

J.D. 242	Est.	Obs.
0958.0	7.4	Ho
79.0	7.4	Ho
84.7	8.0	Ba

162119
U Herculis

J.D. 242	Est.	Obs.
0962.8	11.2	E
79.7	9.9	M
83.7	9.7	Pi
83.7	9.3	Ba

162807
SS Herculis

J.D. 242	Est.	Obs.
0983.7	12.0	Ba

162816
S Ophiuchi

J.D. 242	Est.	Obs.
0960.0	10.2	Ho

163137
W Herculis

J.D. 242	Est.	Obs.
0964.6	8.6	Ba
83.7	8.9	Pi
83.7	9.2	Ba
93.6	9.2	O

163172
R Urs. Min.

J.D. 242	Est.	Obs.
0972.7	9.2	M
73.6	9.4	Pi
73.6	9.4	Bu
84.7	9.1	Ba

163266
R Draconis

J.D. 242	Est.	Obs.
0959.6	7.2	Cr
60.6	7.2	Cr
61.7	7.2	R
64.6	7.3	Ba
71.6	7.7	Cr
72.7	7.5	M
73.6	7.2	O
76.7	7.4	R

VARIABLE STAR OBSERVATIONS Apr.-May, 1915—Continued.

R Draconis

J.D. 242	Est.	Obs.
0979.7	7.7	M
81.6	8.0	Cr
82.6	7.6	Ma
83.7	7.7	Ba
84.6	7.7	O
93.6	7.7	O

164055
S Draconis

0979.7	8.7	M

164319
RR Ophiuchi

0958.0	10.2	Ho
79.0	11.6	Ho

164715
S Herculis

0962.8	7.2	E
79.7	8.0	M
83.7	7.3	Pi
84.7	7.0	Ba

165030
RR Scorpii

0960.0	9.6	Ho
79.0	10.4	Ho

165631
RV Herculis

0962.8	12.5	E
79.7	11.6	M
83.7<12.2		Pi
84.7<13.4		Ba

170215
R Ophiuchi

0962.8	6.9	E
84.7	6.9	Ba

171401
Z Ophiuchi

0962.8	9.0	E
84.7	9.1	Ba

171723
RS Herculis

0983.7	8.5	Pi
84.7	8.2	Ba

172809
RU Ophiuchi

0962.8	11.0	E
80.8	9.5	E
84.6	9.4	Ba

175458
T Draconis

0984.5	10.8	Ba

175519
RY Herculis

J.D. 242	Est.	Obs.
0962.8	13.5	E
80.8<13.4		E
83.7<11.8		Pi
84.7<13.2		Ba

180531
T Herculis

0962.8	11.5	E
79.7<11.0		M
83.7<12.0		Pi

181136
W Lyrae

0958.9	9.6	E
62.8	10.0	E
84.7	11.2	Ba

183308
X Ophiuchi

0962.8	8.9	E
84.7	8.7	Ba

184243
RW Lyrae

0956.9	12.9	E

184205
R Scuti

0956.9	6.0	E
60.0	5.8	Ho
62.9	5.8	E
79.0	5.5	Ho
80.8	5.2	E
84.8	5.8	Bu
84.7	5.2	Ba
92.8	5.2	Pi

190108
R Aquilae

0980.8	11.2	E

190529
V Lyrae

0984.7	10.1	Ba

190926
X Lyrae

0958.9	9.2	E
84.7	9.0	Ba

191019
R Sagittarii

0979.0<11.5		Ho
80.9	12.2	E

191637
U Lyrae

0962.9	11.2	E
84.7	11.0	Ba

192928
TY Cygni

J.D. 242	Est.	Obs.
0880.9	9.4	E
84.7	9.4	Ba

193311
RT Aquilae

0984.7	9.1	Ba

193449
R Cygni

0958.9	10.0	E
62.9	9.6	E
80.9	9.3	E
84.7	9.2	Ba

193509
RV Aquilae

0962.9	9.1	E
80.9	9.1	E
84.7	9.4	Ba

193732
TT Cygni

0958.9	8.2	E
80.8	7.8	E
84.7	7.5	Ba

194048
RT Cygni

0958.9	8.8	E
62.9	8.1	E
80.9	7.7	E
83.8	7.5	Pi
84.7	7.5	Ba

194348
TU Cygni

0958.9<12.4		E
62.9<12.4		E
80.9<12.1		E
83.8<11.7		Pi
84.7<12.5		Ba

194604
X Aquilae

0962.9	11.7	E
84.7	9.8	Ba

194632
χ Cygni

0956.9	8.9	E
80.8	10.3	E
84.7	10.0	Ba

200212
SY Aquilae

0984.7	10.6	Ba

200357
S Cygni

J.D. 242	Est.	Obs.
0962.9<11.4		E

200647
SV Cygni

0962.9	9.0	E
84.7	8.7	Ba

200715a
S Aquilae

0984.8	9.5	Ba

200915b
RW Aquilae

0984.8	9.1	Ba

200812
RU Aquilae

0983.8<12.5		Ba

200916
R Sagittae

0984.8	9.0	Ba

200938
RS Cygni

0983.8	7.8	Pi
84.7	7.2	Ba

201008
R Delphini

0983.8	9.3	Pi

201130
SX Cygni

0962.9<12.6		E

201647
U Cygni

0962.9	8.0	E
83.8	8.4	Pi
84.7	7.8	Ba

202539
RW Cygni

0962.9	8.6	E
84.7	7.9	Ba

202817
Z Delphini

0956.9	11.8	E
83.8	10.9	Pi
83.8	11.0	Ba

202954
ST Cygni

0962.9<11.7		E

202946
SZ Cygni

J.D. 242	Est.	Obs.
0958.9	9.4	E
84.7	9.6	Ba

203226
V Vulpeculae

0983.8	9.3	Ba

203611
Y Delphini

0983.8<12.5		Ba

204318
V Delphini

0983.8<12.5		Ba

205017
X Delphini

0983.8	10.5	Ba

205923
R Vulpeculae

0956.9	10.3	E

210129
TW Cygni

0983.8	12.7	Ba

210868
T Cephei

0984	10.4	Nt

213843
SS Cygni

0456.9	8.2	E
58.9	8.4	E
62.8	9.9	E
62.9	10.0	E
80.8	11.8	E
83.7	11.6	Ba
83.8	11.7	Pi
90.7	11.3	Pi
90.7	11.0	C
91.8	9.8	Pi
92.7	9.6	Pi
92.9	10.0	M

214024
RR Pegasi

0983.8	10.1	Ba

220613
Y Pegasi

0980.9<12.0		E

220714
RS Pegasi

0980.9	12.1	E

No. of observations 711; No. of stars observed 175; No. of observers 17.

The following list of calculated dates of maxima is cited from the "Companion to the Observatory."

June 12	070310	R Can. Min.	June 28	123160	T Urs. Maj.
14	200938	RS Herculis	29	180531	T Herculis
22	142539	V Bootis			

An event of great interest and pleasure to all who participated, (which, owing to lack of space can only be alluded to here), was the meeting of a fortunate group of our members at the home of Mr. D. B. Pickering, in East Orange, N. J., on the evening of May 6th on the occasion of the dedication of Mr. Pickering's splendidly equipped observatory which now crowns the roof-tree of his home. Ten members of the Association were present, and the guests of honor were Mr. Leon Campbell of the Harvard College Observatory staff, than whom no one has done more to promote the welfare of our organization, and Mr. Leon Barritt, the genial editor of the famous "Evening Sky Map" which is doing so much to stimulate interest in Astronomy.

Observations of sun-spots, Venus, Mercury, and Variable stars were made with Mr. Pickering's excellent 3½″ equatorial. Following a bountiful repast, a feature of which was the souvenir presented by Mr. Pickering to his guests, a print of his observatory accompanying a clever and facetious description of the "House that "Pi" built", we had the pleasure of listening to an able paper on the subject of Variables by Mr. Campbell, and later enjoyed a large number of superior lantern slide views of the light curves of Variables, and scenes in the vicinity of Arequipa, Peru, which Mr Campbell described in detail.

The occasion was a red letter one in the history of the Association, and the cordial reception, the charm and hospitality of the Pickering home will live long in the memory of all who were fortunate enough to be present.

The following members contributed to this report:—Messrs. Bancroft, Bouton, Burbeck, Crane, Eaton, Hoge, Mach, McAteer, Miner, Mundt, Nolte, Olcott, Pickering, Richter, Vrooman, Whitehorn, Miss Young.

The Hagen traced chart of 115919 R Comae is defective. Will observers using this chart please return their print to the secretary when a correct chart will be sent them.

WILLIAM TYLER OLCOTT,
Corresponding Sec'y.

Norwich, Conn.
May. 10, 1916.

COMMUNICATIONS.

A Peculiar Aurora.—A brilliant and very peculiar aurora was visible at Pittsburgh on Friday, April 28. Its presence was noted soon after dark. I first saw it at 10 o'clock. It then consisted of a beam of light exactly resembling a search-light extending vertically upward from near the horizon at a point about twenty degrees north of west, and three or four degrees south of Venus. The length was approximately thirty degrees and the width increased slowly to about three degrees at the top. From the thirty degree elevation it extended feebly to the zenith, or possibly a little beyond, the southern boundary being continuous with a strong beam, while to the north it widened suddenly. This part for a time consisted of a

number of short vertical shafts of light, rather bright, and separated by feebler luminosity. The whole width of this part was perhaps thirty degrees. A half hour later it had practically all disappeared. At midnight a straight shaft of light extended from north-west to south-east at least one hundred and fifty degrees long, disappearing at either end in the pall of smoke which overhung the city. It was inclined about fifteen degrees to the east and west line. Arcturus, which was at that time near the meridian, was just on the northern edge of the beam which was nowhere more than three degrees wide, and varied little from end to end. It wavered somewhat, and at one time was considerably disturbed in the neighborhood of the meridian.

This beam lasted about half an hour, gradually fading away. There was no further manifestation of auroral activity during the night. Neither this beam nor the earlier one showed any color.

FRANK C. JORDAN.

Allegheny Observatory,
Pittsburgh, Pa. April 29, 1916.

An Unusual Aurora.—I wish to tell you of a beautiful phenomenon which occurred April 27. About 10:21 I noticed a small patch of light in the east. I turned away and less than a minute later I looked back, when to my surprise this seemingly inconspicuous light had hurled itself across the sky in a beautiful path about 5 degrees in width. It lingered until about 10:51 then faded away.

PHILIP TRUDELLE.

Chippewa Falls, Wis.

The Aurorae of April 27th and 28th.—While I was out observing meteors on the 27th of April, aurorae began to show up about 8:30. They were faint, nebulous and a pale green. They slowly mounted toward the zenith and grew brighter as they did so. About 10:20 I looked over in the east and saw a pale yellow streamer of light that looked like a great comet tail. It stayed like this for five minutes then it widened in the center and got narrow on the ends. It extended from the horizon up into the sky along the ecliptic about 60° and was about 4° wide. At 10:25 it began to grow longer at 10:26 it had completely stretched across the sky from east to west along the ecliptic. It passed above Virgo, above Leo and between Castor and Pollux. At 10:30 it shifted 10° south so that it passed directly along the ecliptic. About 11:30 it had completely faded away. When it started, sharp flashes of purple light came from the northern horizon and swept upward to the zenith. They followed one another about 30 per minute. At 12 o'clock bands of light came from the northern horizon that were about 3° wide, stretching from east to west. They mounted zenithward and would suddenly disappear when they reached Polaris.

On the 28th the band along the ecliptic appeared again and went through similar changes. It disappeared about 9:15. The aurorae became more brilliant than they were on the 27th of April.

JOHN KOEP.

Chippewa Falls, Wis.

A Striking Aurora.—At about 10:40 p. m. April 27 a bright band of white light was seen stretching across the whole sky from a point a little north of west to a point a little south of east. Passing between Castor and Pollux, which were near the western horizon, it crossed the meridian south of the zenith and passed over Arcturus, touching the eastern horizon at a point about 15° south of the western end of the arc. The arc moved slowly southward the western end

appearing to act as a pivot. At the same time the band, which at first was slightly wider than a rainbow, became wider and more diffuse. This occurred more rapidly in the eastern than in the western part. In about half an hour the light had nearly died out. About a quarter to twelve another band similar to the first but much shorter was seen. It extended from a point east of Arcturus nearly to the eastern horizon. This one in fading out formed a second very faint streak which was visible for just a moment parallel to the main one.

The next night two more bands were seen, both stretching across the whole sky. The first was noticed at about five minutes past nine. At this time it was more diffuse than those of the previous night were when first observed, and it was brighter in the eastern than in the western part. It disappeared in about twenty minutes. Later in the evening another still fainter band was seen.

Ordinary forms of aurora borealis were also observed on both evenings.

FRANZ M. EXNER.

Northfield, Minn.

GENERAL NOTES.

The next issue of POPULAR ASTRONOMY, the August-September number, will appear about August 1.

Professor George E. Hale gave an account of the progress of his study of solar phenomena, at the meeting of the American Academy of Sciences in Boston on May 10.

Professor W. H. Pickering, who has been making extensive observations on Mars for the past few years in Jamaica, is at present at the Harvard College Observatory.

Mr. Bernhard H. Dawson, who has been studying at the University of Michigan, will leave some time in July to resume his position as astronomer in the Observatory of LaPlata.

Professor H. C. Wilson, who is spending this semester in Harvard College Observatory as Visiting Lecturer in Harvard University, lectured before the students in astronomy at Mt. Holyoke on Saturday May 13. The subject of his lecture was "A Trip to the Moon."

Dr. William Frederick King, Director of the Dominion Observatory at Ottawa, and Astronomer Chief for Canada, died at his home on Sunday April 23. An account of the life and work of Dr. King is given by Professor C. A. Chant, as the first article in this issue.

Professor Ralph H. Curtiss has been granted a leave of absence by the Board of Regents of the University of Michigan for two or three years. Professor Curtiss will go to Argentina to inaugurate stellar spectroscopic work at the Observatory of the University of LaPlata. Leave of absence was also granted to Mr. H. J. Colliau, who will accompany Professor Curtiss and assist in installing the spectrograph and other apparatus.

The Public Observatory at Sound Beach, Conn., is in need of an additional telescope. The director Mr. Edward F. Bigelow, requests us to announce that he should like either a gift of a telescope, a three or four inch mounted on a tripod, or money to obtain one.

The 72-inch Reflecting Telescope, designed and constructed for the Dominion Astronomical Observatory, Victoria, Canada, by the Warner and Swasey Company, has been completed. An exhibition of this instrument was held in the factory of the makers at 5701 Carnegie Avenue, Cleveland, on May 26, 1916. Invittaions to be present at the exhibition were sent to astronomers and others throughout the country who were interested.

Telescope Presented by a College Class.—The class of 1916 of Millsaps College became so much interested in the photographing of the solar eclipse, described elsewhere in this number, that the class has purchased the telescope with which the photographs were made and has presented it to the college. Professor Harrell states that he has secured good results upon nebulae with it.

The Heavens is the name of a monthly publication of the Astronomical Society of Los Angeles. It was begun in April, and two issues have reached us. It is to be a "Monthly Record of the Stars, Planets and Astronomical Events." It is designed to answer the numerous untechnical questions which arise. The subscription price is one dollar a year.

Reader's Guide Supplement.—The readers of this journal will be pleased to learn that this is one of those journals whose contents are indexed in the *Reader's Guide Supplement* published by the H. W. Wilson Company, White Plains, N. Y., and to be found in many of the public libraries. The *Supplement* is issued in January, March, May, September and November, each issue including all the preceding ones for the year, beginning with the March issue. The annual subscription price to this *Supplement* is determined by a sliding scale depending upon the number of magazines which are subscribed for by a given library and indexed in the *Supplement*. It doubtless will be found of great use in locating papers relating to a given topic.

The Allegheny Observatory.—It was with much regret that I read the last paragraph on page 334 of the May issue of POPULAR ASTRONOMY. Mr. Bigelow visited our observatory not long ago and we gave him every facility to study the same and to see the wonderful work that is being done here, and then to comment as he has done in his article on "The greatest need of astronomy" is something I cannot understand, although he says he does it in no spirit of adverse criticism. His general comment on the observatories of the United States as "a failure and a farce" is certainly discreditable to Mr. Bigelow, and particularly when he bases it upon the fact that the observatories are not contributing to the instruction of the public.

I agree with him that it would be a splendid thing to have a free observatory in every town and two or three in every city of the United States, for I saw the time myself when, as a workman in the rolling mill, I would have given almost anything I owned to have the pleasure of studying the heavens in a telescope, and I determined that if ever I had an opportunity or could make one, I would use my

best efforts to have an observatory open to the people, and we have now put up this beautiful observatory with one of its departments forever free to the people in which we have placed the 13-inch telescope nicely remounted, which is as efficient as any new telescope of 12-inch aperture, and we also have a beautiful lecture room connected with it.

We are also making preparations to put up another observatory, to be forever free to the people, which is to be placed in Schenley Park in the East End, so that residents of the districts far away from us can be accomodated.

Mr. Bigelow says:—"But what amuses me is that the people of Pittsburgh and Allegheny think that they have an observatory. They have nothing of the kind. The technical workers have an observatory. I sincerely hope they will keep it and make good use of it, but what I am pleading for is that those cities and every other city in the United States will establish an observatory that shall be for the people and not exclusively for the few who are skilled in technical research." I confess I cannot understand this, from the fact that while the Allegheny Observatory, with the work of its director and its splendid corps of assistants, takes very high rank in the domain of astrophysical and astronomical research, its free department which has been open for six years, during every month in the year that was at all favorable for observation, has afforded over nineteen thousand people an opportunity of seeing objects in the telescope, with a descriptive lecture by members of the staff or a member of the local astronomical society. When the nights are unfavorable, the visitors are taken into the lecture room of the observatory, designed and fitted up purposely for the public, where lectures are given, illustrated with lantern slides, and as we have command of many hundred slides, they can always spend a pleasant and profitable evening, although our good friend says, "It has not lifted in the slightest degree the shades of ignorance that obscure the heavens."

Mr. Bigelow also speaks of us using "the small telescope" made by Alvan Clark, "the same that Langley used more than half a century ago." Let me say that even this telescope of 13-inch aperture is too large for general use, and were I to advise as to a telescope for a public observatory, I would not think of having one over 10-inch aperture, from the fact that you can use a 10-inch telescope for visual purposes under general atmospheric conditions in which observations have to be made, at least ten times where you could use a 30-inch once. It is a pity that Mr. Bigelow does not know this, as he criticizes our people, saying that our 30-inch "has never been and never will be looked through by even one citizen of Pittsburgh or Allegheny, because it is not adapted to visual observations; it is a photographic lens." This is a false statement as, while the great lens is corrected for photographic purposes, it has a visual correcter and only a few nights ago a visiting group had some beautiful observations of the planets in this telescope.

We also have an astronomical society in Pittsburg, composed almost entirely of those who from time to time have the use of the telescope. This society meets in the lecture hall, and the staff of the observatory give occasional talks of value to those who attend the meetings. Last week the address was on the Herschels, by Miss Bender of the observatory staff.

Reading Mr. Bigelow's article called "An open letter to Mr. Andrew Carnegie" in the Guide to Nature, I can tell him why it was possible to raise such a large sum of money for the Allegheny Observatory and equipment. It was because of the splendid record that has been made in the institution of the very kind of work which he condemns, much of which is known and understood by the laymen interested in astronomical studies.

In closing this already too lengthy note, let me say there are many observa-

tories, east and west, some, like the splendid institution at Oakland, California, presided over by that enthusiastic astronomer Professor Charles Burckhalter are always open to the rank and file of the lovers of astronomy. Then the Lick Observatory, also in the far west; the Flower Observatory in the east—yes, even the United States Naval Observatory is open to visitors. I could name others that are ever ready to lend a helping hand to the lovers of the stars, and let me say astronomers all over this land have been giving lectures for the past twenty-five years, nine tenths of them free to the people. Pardon me if I put in a little of the ego by saying I have given over four hundred lectures in the last quarter of a century on the beauties of the heavens, and propose to keep it up until my hearers get tired of me or these old vocal organs fail to respond to my wish and will.

JOHN A. BRASHEAR.

Pittsburgh, Pa.
May 13, 1916.

Actual Time of Signals from the U.S. Naval Observatory, April, 1916.

Day	Time of signals Noon.			Error	Time of signals 10:00 p.m.			Error	
	h	m	s		h	m	s		
1	12	0	0.03	+.03	10	0	0.05	+.05	
2	12	0	0.07	+.07	10	0	0.10	+.10	Sunday
3	12	0	0.09	+.09	10	0	0.10	+.10	
4	12	0	0.11	+.11	10	0	0.13	+.13	
5	12	0	0.13	+.13	10	0	0.15	+.15	
6	12	0	0.11	+.11	10	0	0.12	+.12	
7	12	0	0.02	+.02	10	0	0.01	+.01	
8	12	0	0.00	.00	10	0	0.03	+.03	
9	12	0	0.04	+.04	10	0	0.03	+.03	Sunday
10	11	59	59.99	−.01	9	59	59.97	−.03	
11	11	59	59.97	−.03	9	59	59.98	−.02	
12	11	59	59.96	−.04	9	59	59.96	−.04	
13	12	0	0.04	+.04	10	0	0.01	+.01	
14	12	0	0.01	+.01	10	0	0.02	+.02	
15	12	0	0.03	+.03	10	0	0.02	+.02	
16	12	0	0.03	+.03	10	0	0.01	+.01	Sunday
17	12	0	0.01	+.01	10	0	0.03	+.03	
18	12	0	0.02	+.02	10	0	0.01	+.01	
19	12	0	0.00	.00	10	0	0.02	+.02	
20	12	0	0.03	+.03	10	0	0.00	.00	
21	12	0	0.02	+.02	10	0	0.02	+.02	
22	12	0	0.03	+.03	10	0	0.02	+.02	
23	12	0	0.04	+.04	10	0	0.02	+.02	Sunday
24	11	59	59.99	−.01	9	59	59.98	−.02	
25	11	59	59.98	−.02	9	59	59.98	−.02	
26	11	59	59.98	−.02	9	59	59.95	−.05	
27	11	59	59.94	−.06	9	59	59.97	−.03	
28	11	59	59.95	−.05	9	59	59.94	−.06	
29	11	59	59.99	−.01	10	0	0.01	+.01	
30	12	0	0.01	+.01	10	0	0.00	.00	Sunday

Maximum error: Apr. 4, +0.15 sec.

Constant to be added to above errors to give error of radio signals from

Arlington +0.02 sec.
Key West +0.27

J. A. HOOGEWERFF,
Captain U.S. Navy
Superintendent.

U.S. Naval Observatory,
Washington, D. C.
May 5, 1916.